

БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ **ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО** **И РОБОТИКА (ИСИР-БАН)**



Introduction to CMS and its Electromagnetic Calorimeter system – design considerations, overview of the construction and function of the ECAL and Bulgarian Experience

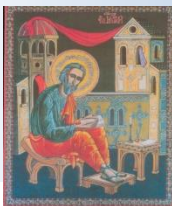
Въведение в системната конструкция на CMS експеримента и неговия Електромагнитен калориметър (ECAL), описание на конструкцията и действието на ECAL и Българския опит

Проф. д-р инж. Роман Захариев

зам. директор на ИСИР-БАН

**Национална учителска програма за
квалификация на инженери - педагози**

Женева, 04-10.10.2015 г.



ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА - БАН



ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА-БАН е един от инженерните институти на Българска академия на науките, София.

На 01.07.2010 г. ИСИР-БАН беше основан съгласно препоръката, отправена от проведения Европейски одит на БАН на основата на две много високо оценени научни звена като бившия Институт по управление и системни изследвания (ИУСИ - БАН) и бившата Централна лаборатория по мехатроника и приборостроене (ЦЛМП-БАН) и беше наречен:

“Институт по ситемно инженерство и роботика (ИСИР-БАН)”



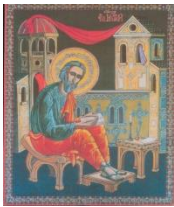
АДРЕС:

Ул. “Акад.Г.Бончев” бл.2

1113 Sofia/ Bulgaria

<http://www.bas.bg/clmi/>

<http://www.bas.bg/icsr/>



Приноси на ИСИР-БАН в работата на L3 Detector at LEP



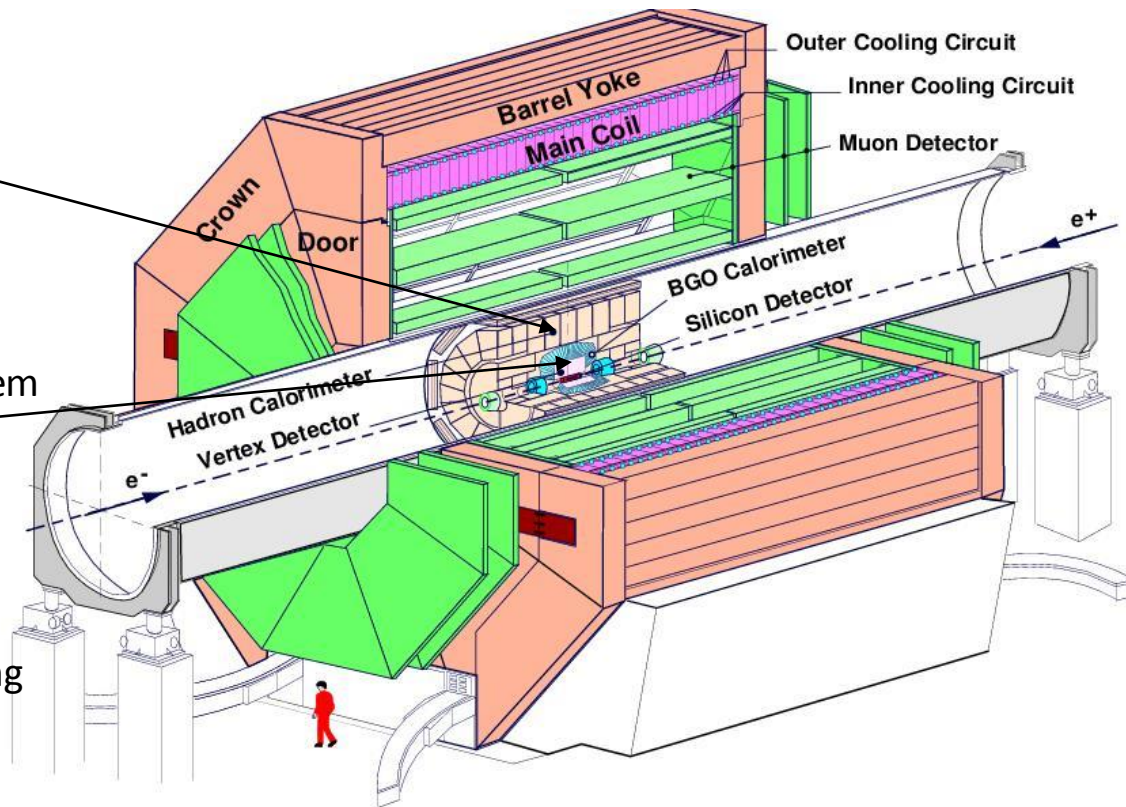
Участие в създаване на: Hadron Calorimeter

- Electronic integration of all 144 modules
- Design and production of HV system, including control and monitoring system

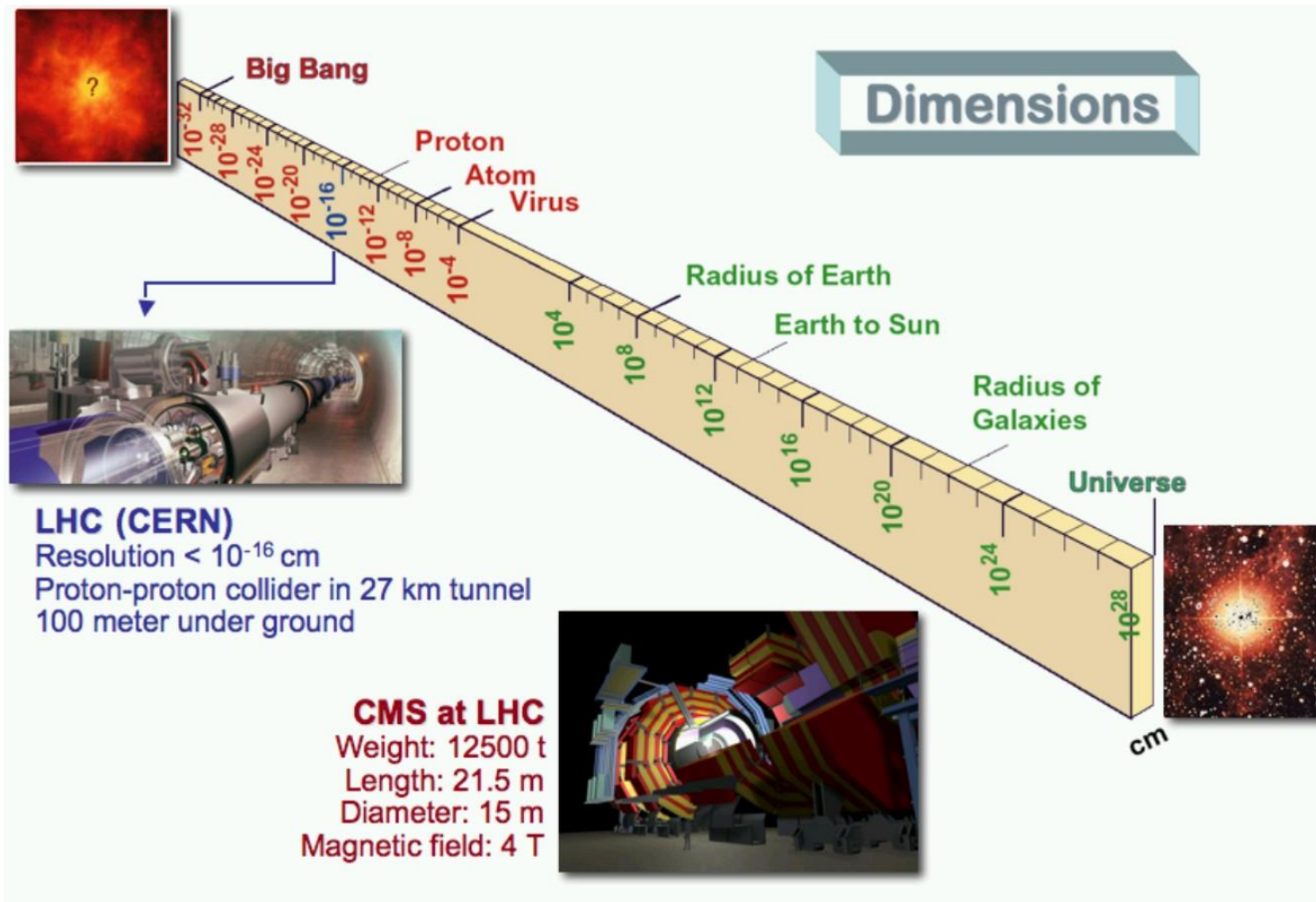
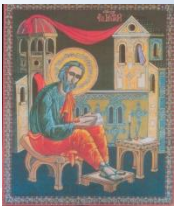
TEC (Time Expansion Chamber)

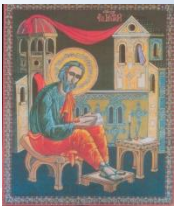
- Participation in construction
- Mechatronics of Central Tracking cabling

Техническа поддръжка по време на експлоатацията на L3 detector

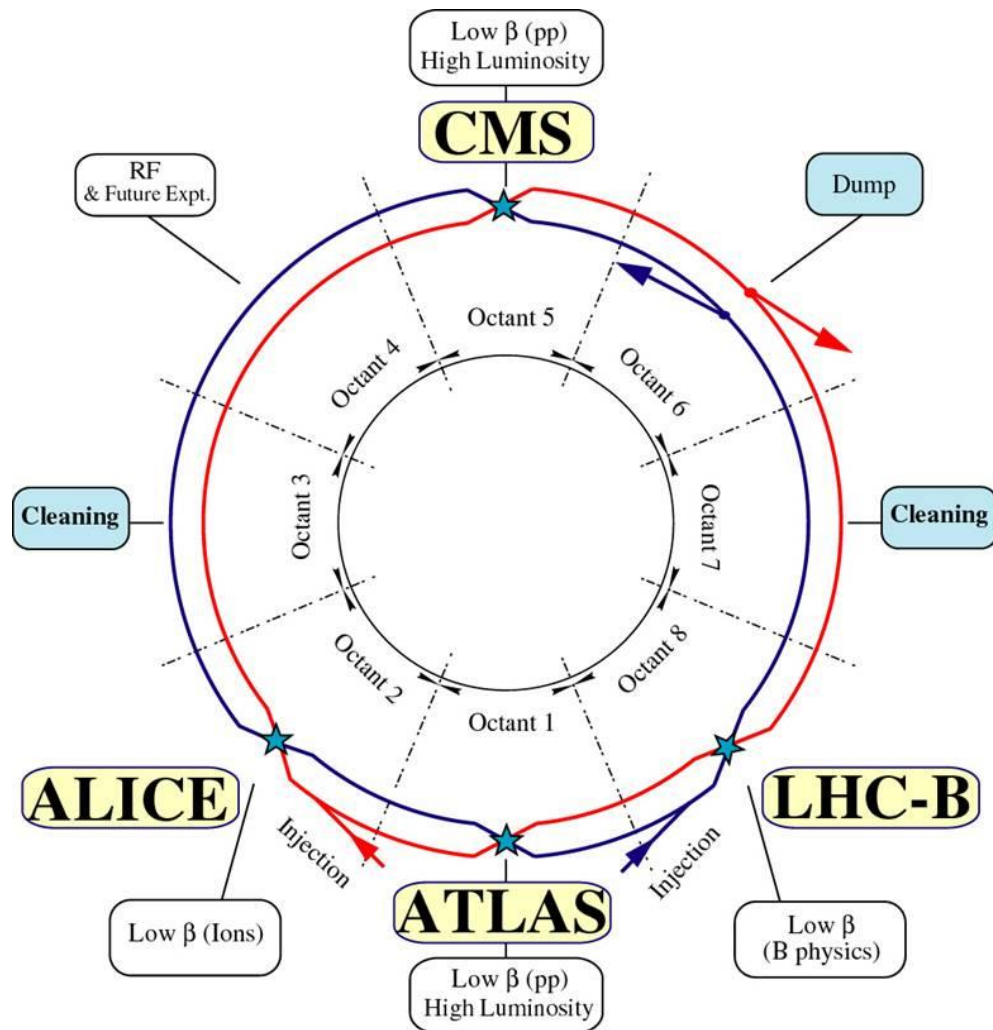


All activities were carried out in the framework of a collaboration agreement with the Institute for High Energy Physics of ETH Zurich



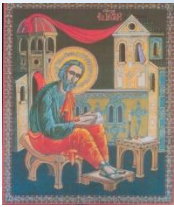


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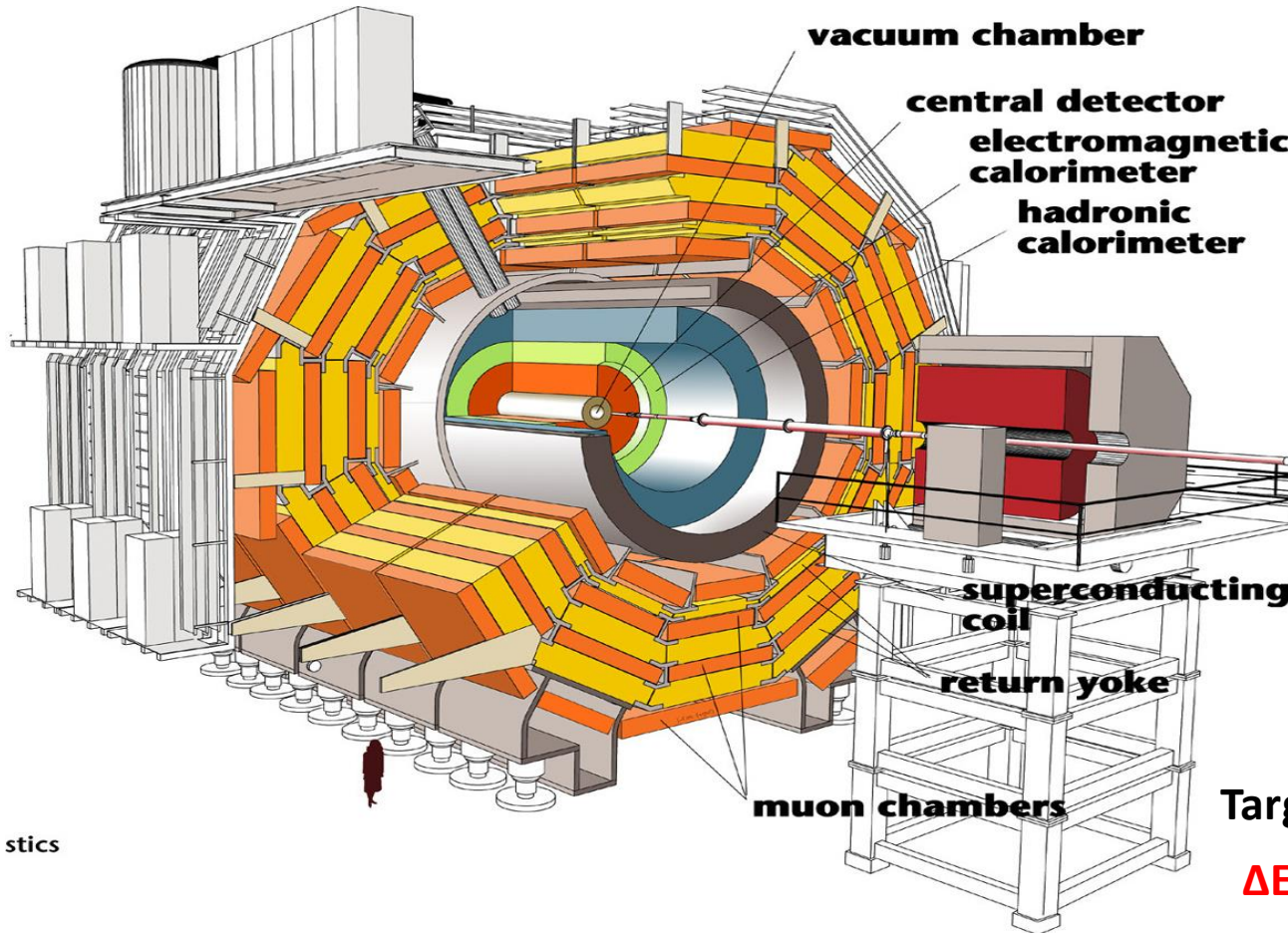


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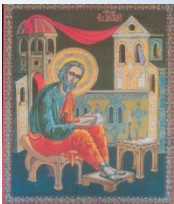


Compact Muon Solenoid



Target → high resolution ECAL

$\Delta E/E \sim 0.5\%$ for $E > 100$ GeV



България в CMS



ИЯИЯЕ - БАН

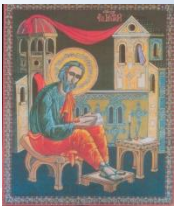


**СУ „К. Охридски“,
Физически ф-тет.**



ИСИР - БАН (ЦЛМП-БАН)

(чрез ЕТН, Цюрих)



42 страни, 182 Института, 2680 учени, 891 студенти

31 Nations, 150 Institutions, 1870 Scientists

CMS детектор

TRIGGER & DATA ACQUISITION

Austria, CERN, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Switzerland, UK, USA

TRACKER

Austria, Belgium, CERN, Finland, France, Germany, Italy, Japan*, Switzerland, UK, USA

CRYSTAL ECAL

Belarus, CERN, China, Croatia, Cyprus, France, Italy, Japan*, Portugal, Russia, Switzerland, UK, USA

PRESHOWER

Armenia, Belarus, CERN, Greece, India, Russia, Taiwan (PC), Uzbekistan

RETURN YOKE

Barrel: Czech Rep., Estonia, Germany, Greece, Russia
Endcap: Japan*, USA

SUPERCONDUCTING MAGNET

All countries in CMS contribute to Magnet financing in particular:
Finland, France, Italy, Japan*, Korea, Switzerland, USA

FEET
Pakistan
China

FORWARD CALORIMETER

Hungary, Iran, Russia, Turkey, USA

HCAL

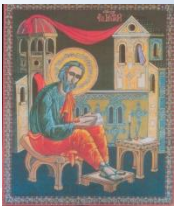
Barrel: Bulgaria, India, Spain*, USA
Endcap: Belarus, Bulgaria, Russia, Ukraine
HO: India

MUON CHAMBERS

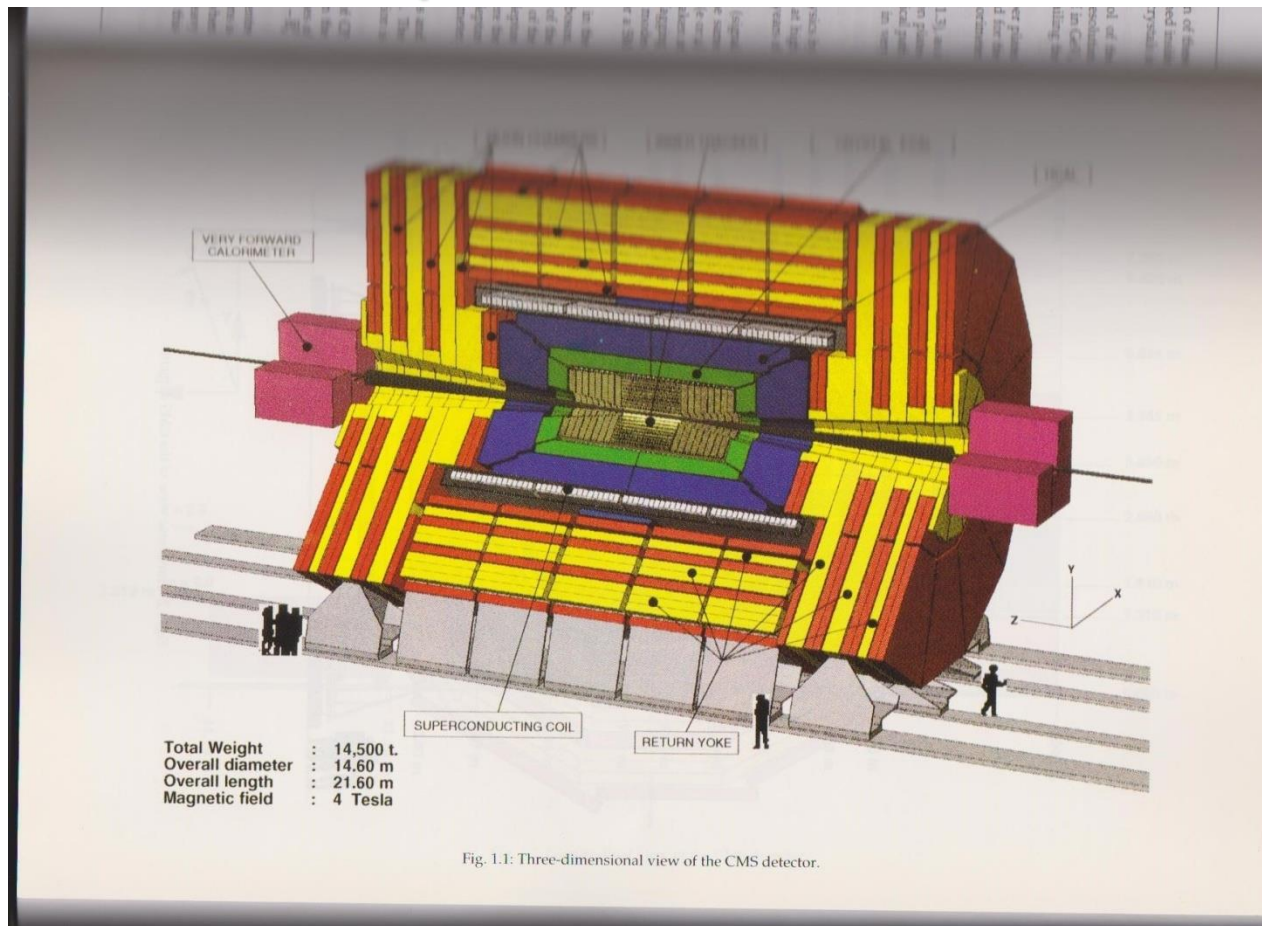
Barrel: Austria, Bulgaria, CERN, China, Germany, Hungary, Italy, Spain, Belarus, Bulgaria, China, Korea, Pakistan, Russia, USA

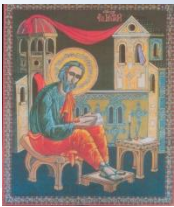
Total weight : 12500 T
Overall diameter : 15.0 m
Overall length : 21.5 m
Magnetic field : 4 Tesla

* Only through industrial contracts

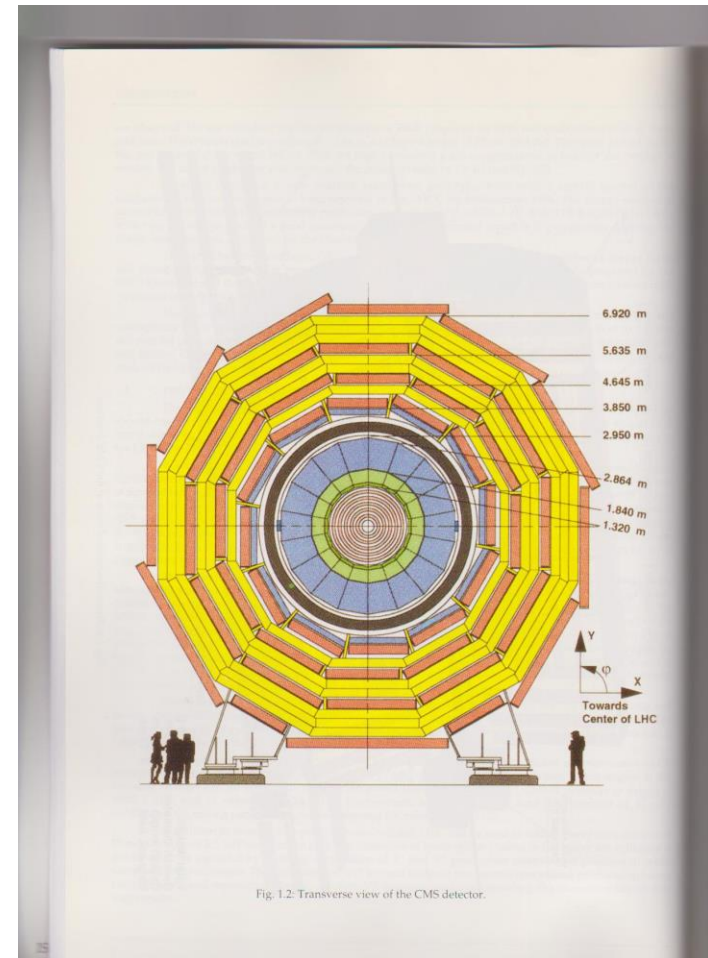


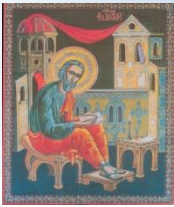
Compact Muon Solenoid





Напречен разрез на CMS Experiment на CERN

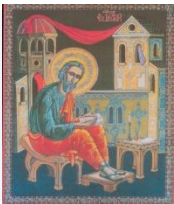




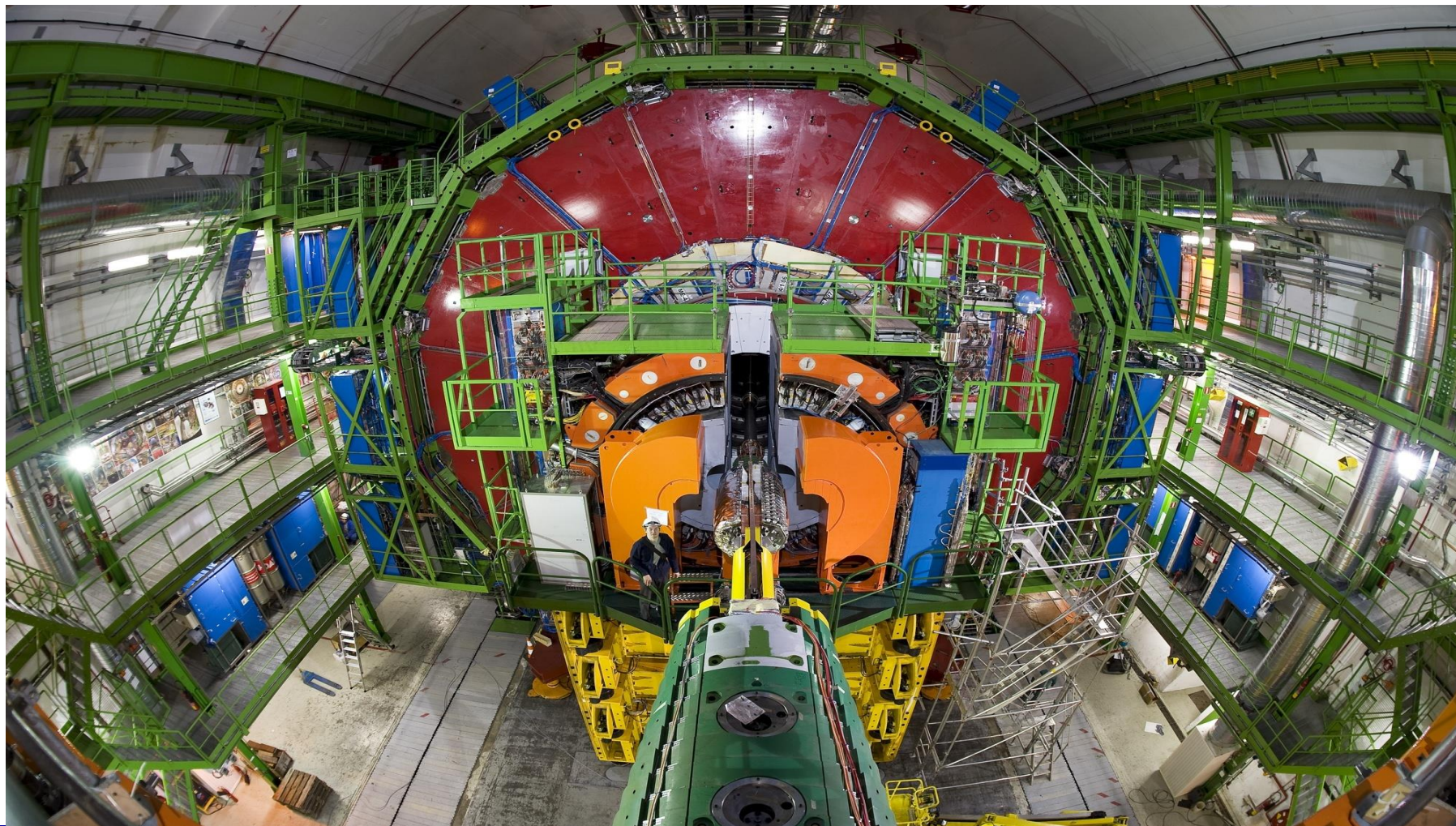
Status CMS operational detectors

Sub-detector	No. of ch.	Working (%)
Pixels	66×10^6	98.6 (+ ...)
Silicon strip detector	9.3×10^6	98.3 (+0.6%?)
ECAL PbWO ₄ calorimeter	7.58×10^5	99.5
ECAL ES	1.37×10^5	99.95
HCAL HB (HO) calorimeter	2592 (2160)	100 (99.1)
HCAL HE calorimeter	2592	100
HCAL_HF calorimeter	1728	100
Muon DTs	1.55×10^5	99.6
Muon CSC (CFEB)	2.18×10^5	99.3
Muon RPC RB (RE)	$8.3(4.1) \times 10^4$	99.7 (99.5*)

CMS comprises 66M pixel channels, ~ 9.3M Si microstrip ch, ~76k crystals, 150k Si preshower ch, ~15k HCAL ch, 250 DT chambers (170k wires), 450 CSC chambers (~200k wires), 480 Barrel RPCs and 432 endcap RPCs, muon and calorimeter trigger system, 50 kHz DAQ system (~ 10k CPU cores), Grid Computing (~ 50k cores), offline (> 2M lines of source code).

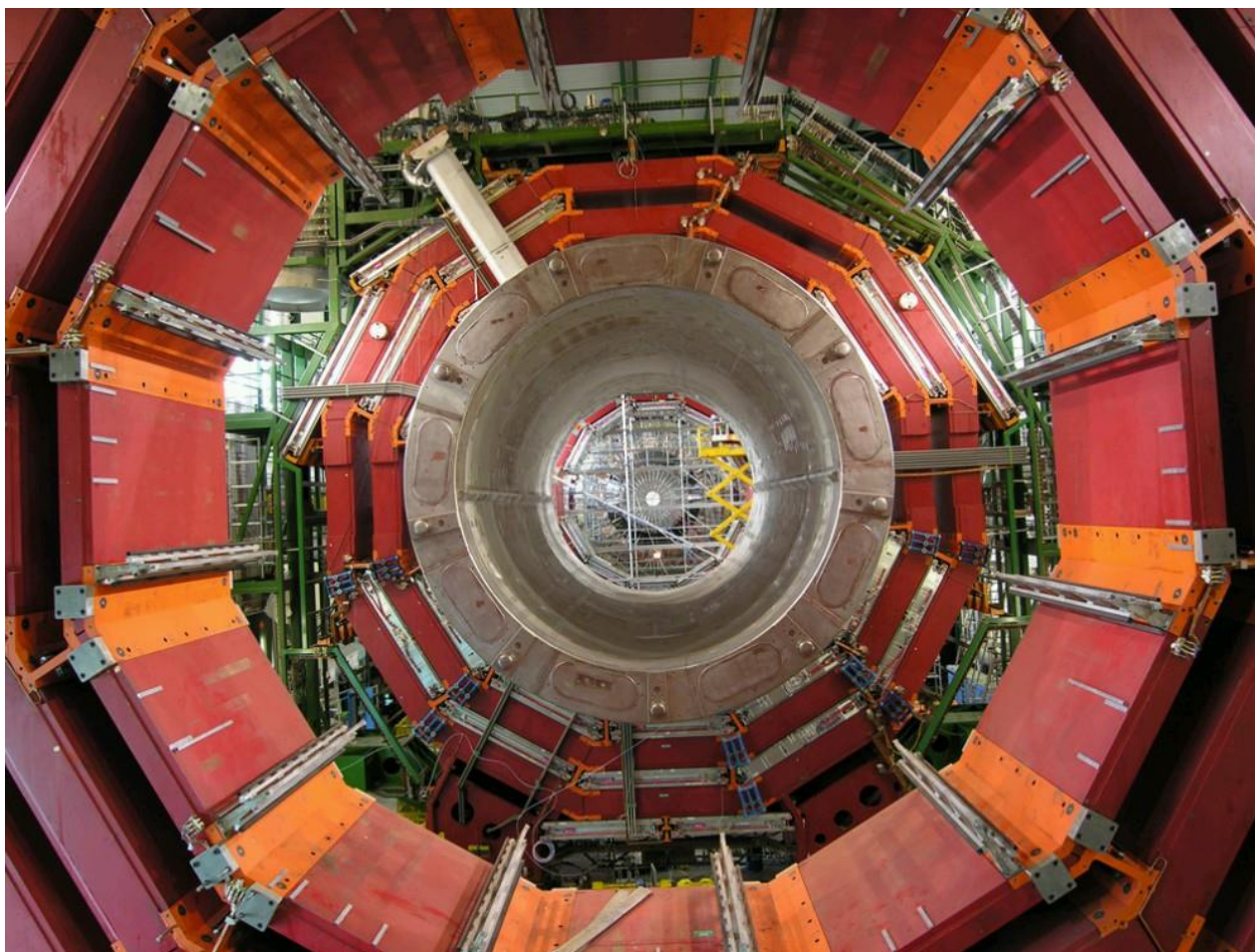
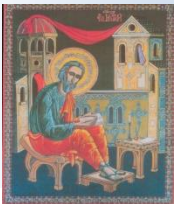


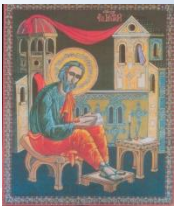
ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА-БАН



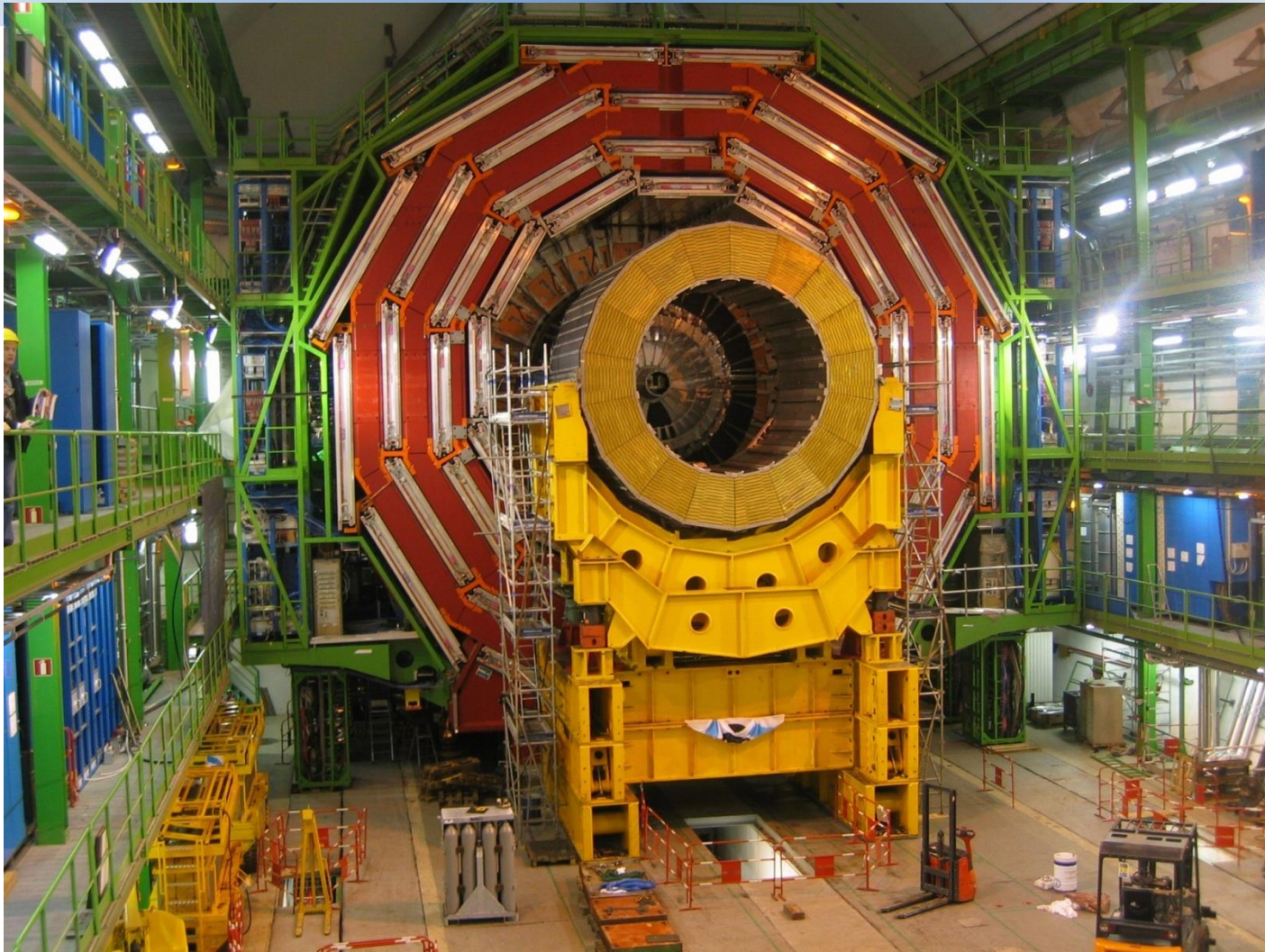
Национална учителска програма за квалификация на инженери - педагози

Женева, 04-10.10.2015 г.



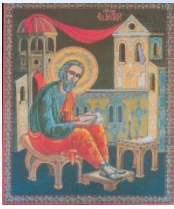


ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА - БАН

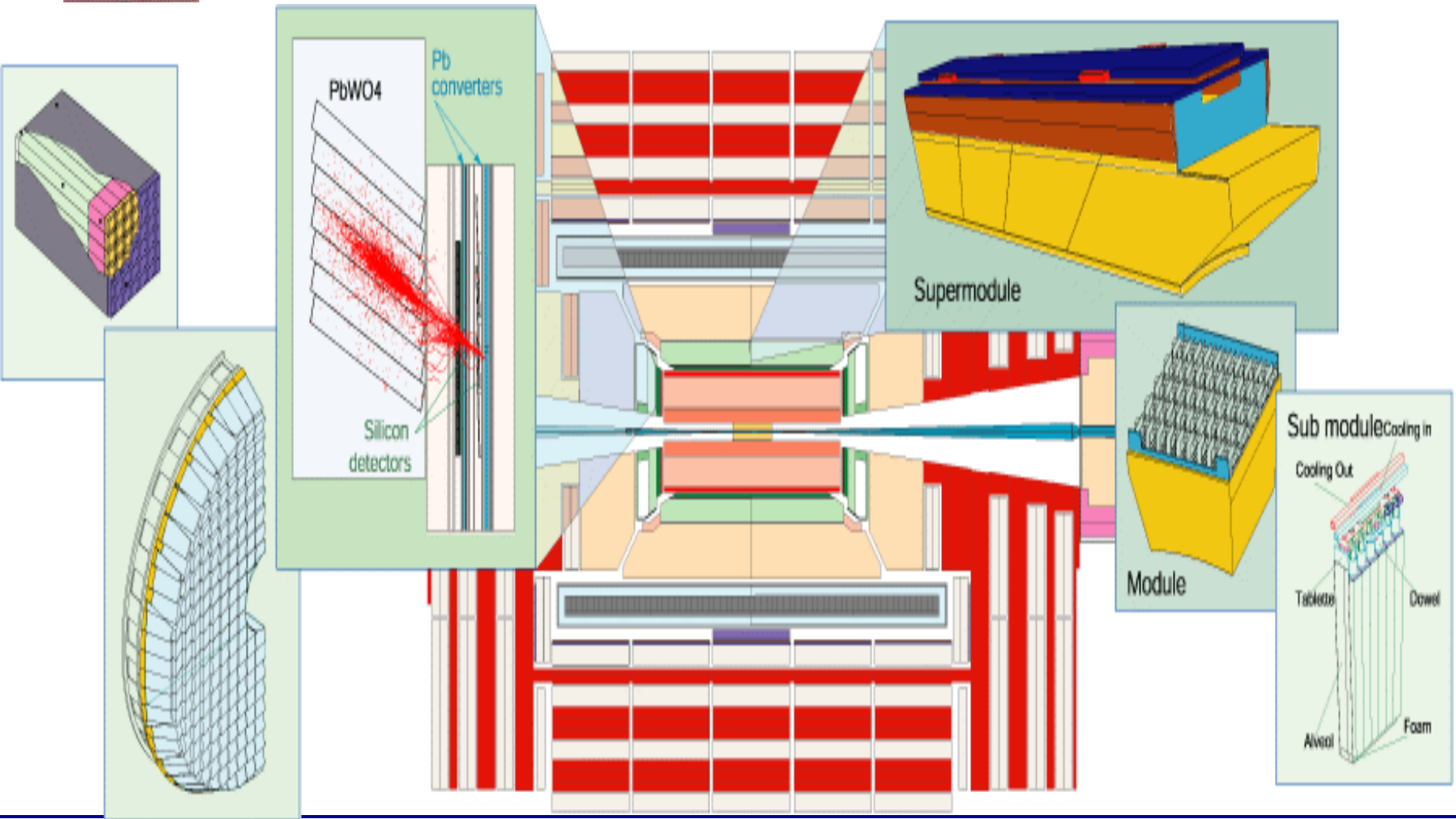
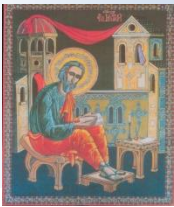


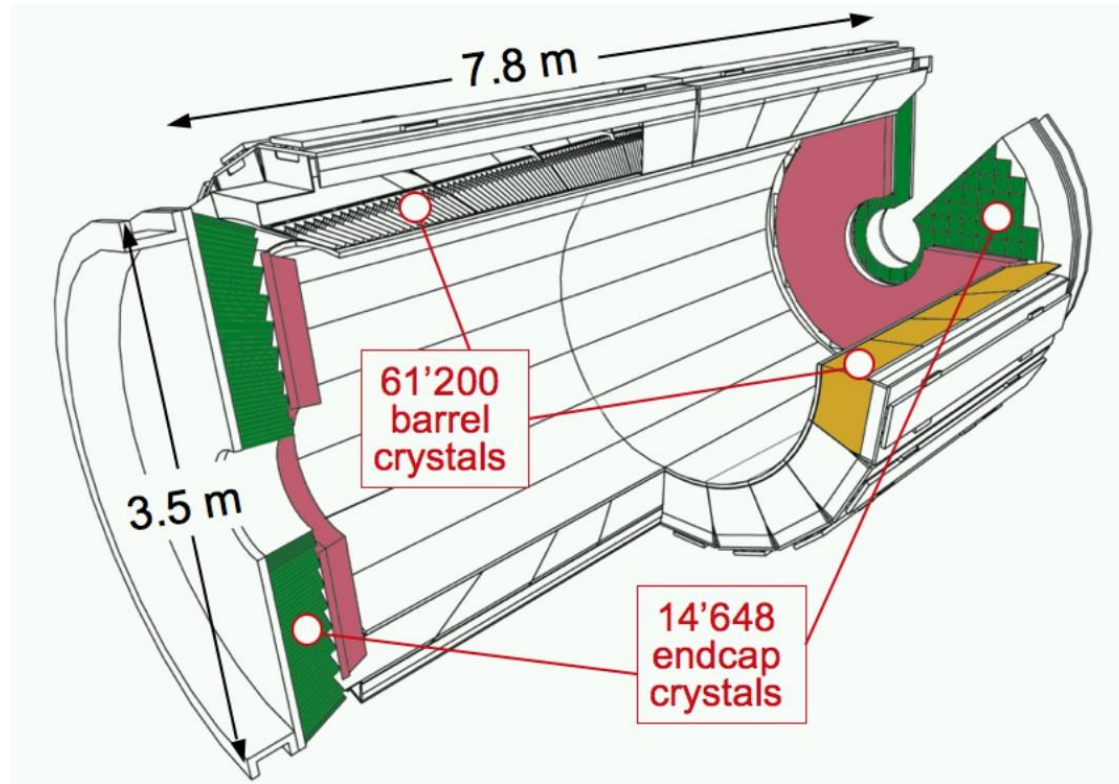
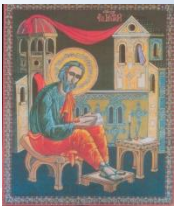
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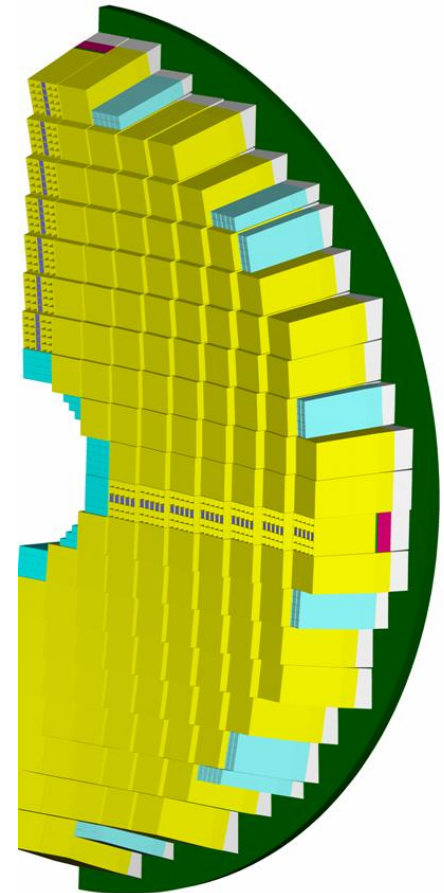


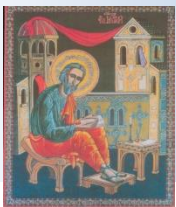
The Electromagnetic Calorimeter in CMS Experiment of CERN



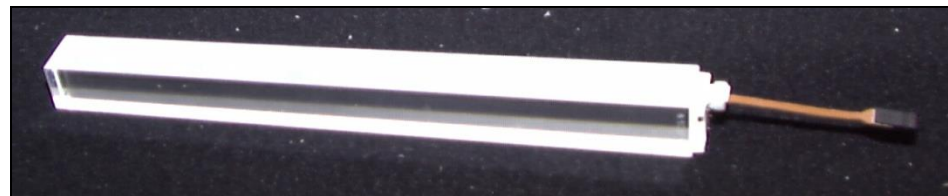
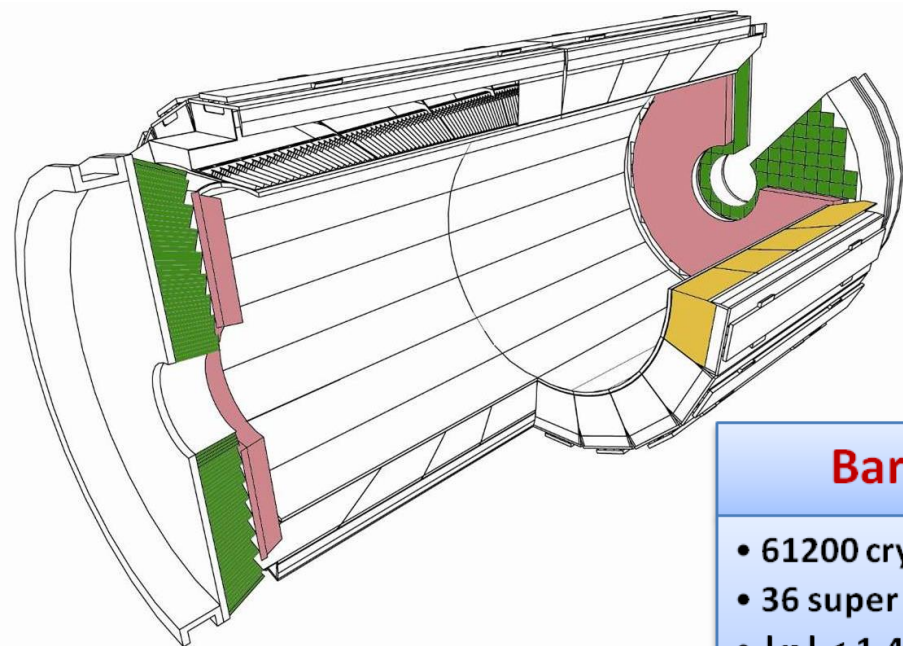


Supermodul





УСТРОЙСТВО НА ЕЛЕКТРОМАГНИТНИЯ КАЛОРИМЕТЪР



Barrel

- 61200 crystals
- 36 super modules
- $|\eta| < 1.48$
- $\sim 26 X_0$

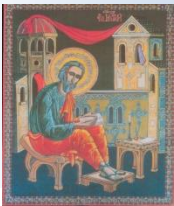
End Caps

- 14648 crystals
- 4 Dees
- $1.48 < |\eta| < 3$
- $\sim 25 X_0$

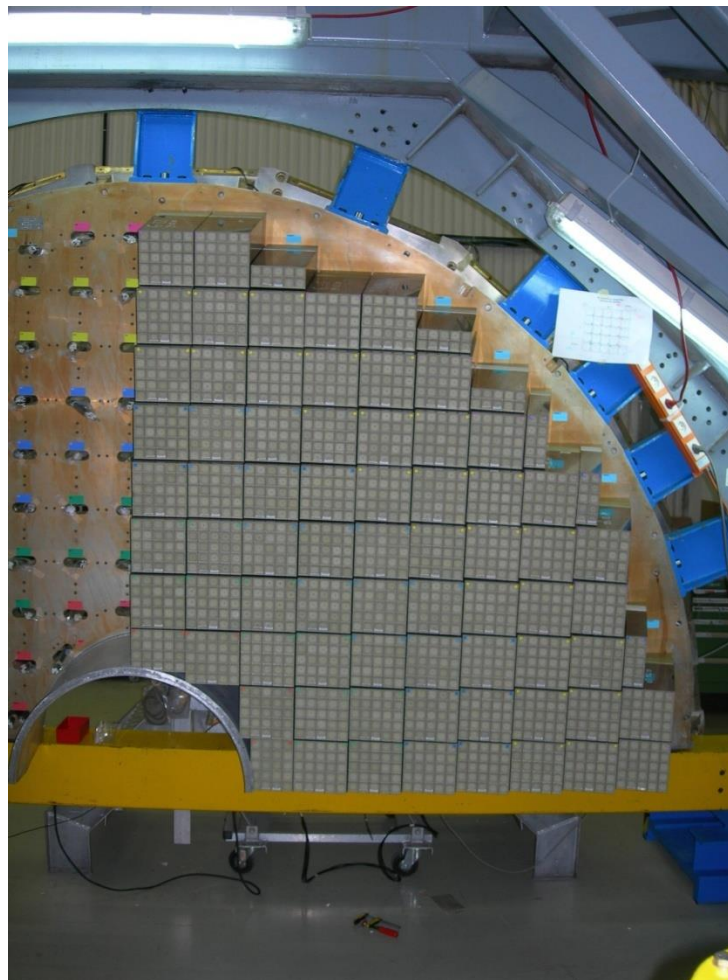
Preshower

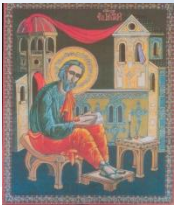
- Pb/Si
- $1.65 < |\eta| < 2.6$
- $3 X_0$

Lead Tungstate crystals (PbWO₄)
Fast scintillation: 80% of the light collected in 25 ns



кристали
 PbWO_4





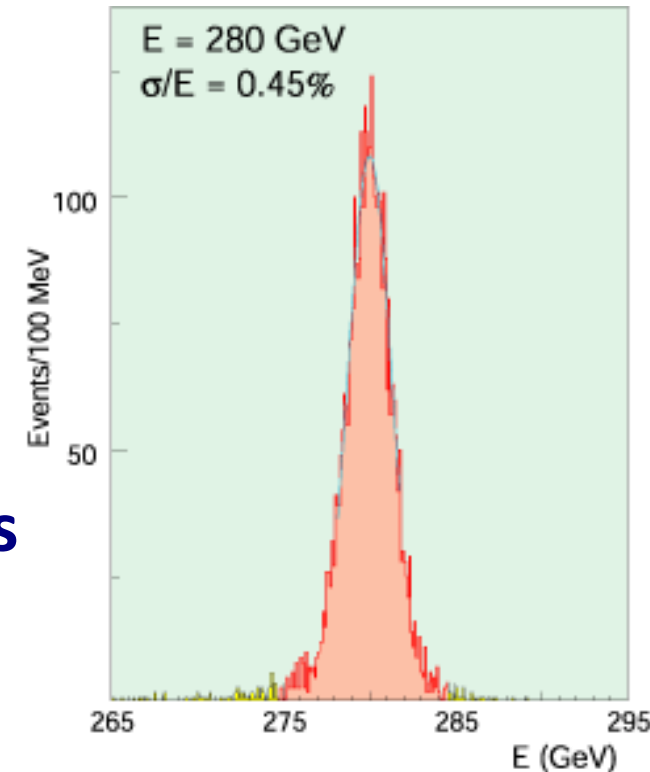
КРИСТАЛИ

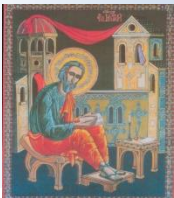


Lead Tungstate crystals (PbWO₄)

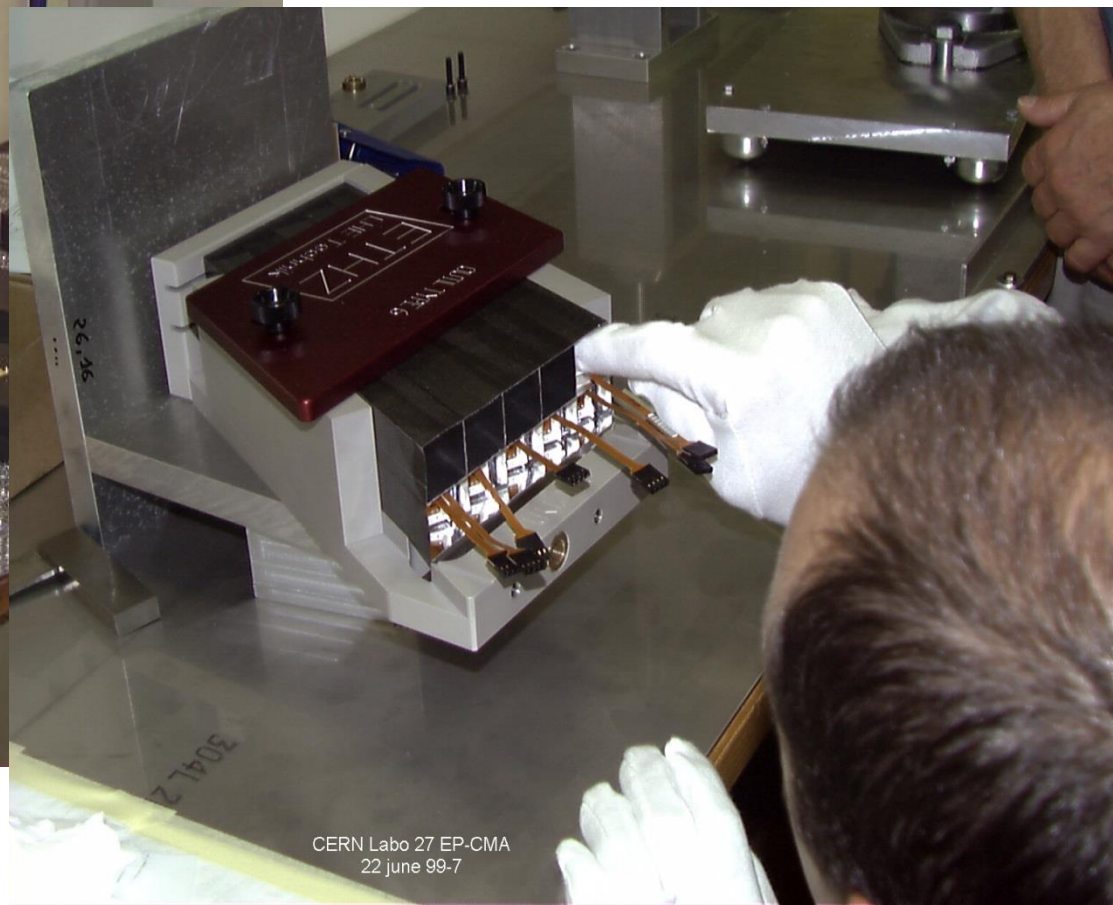
Характеристика:

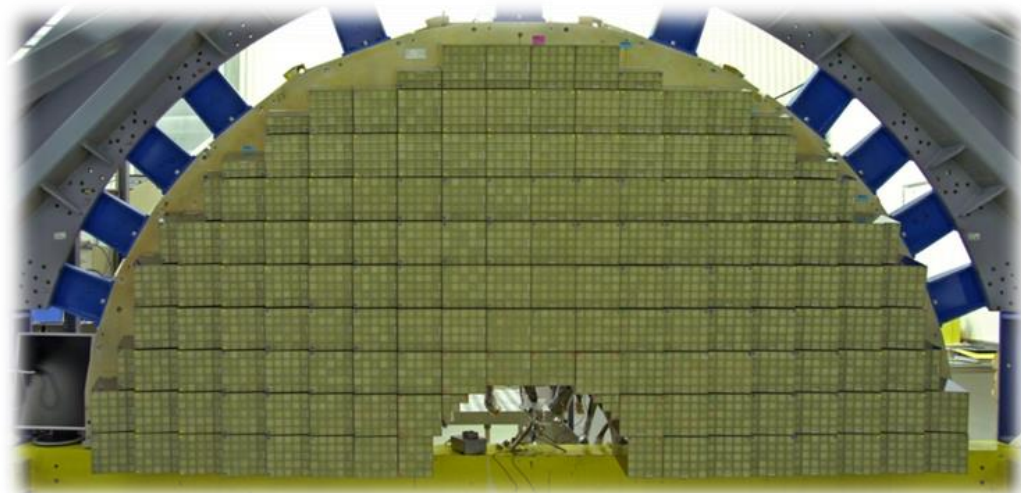
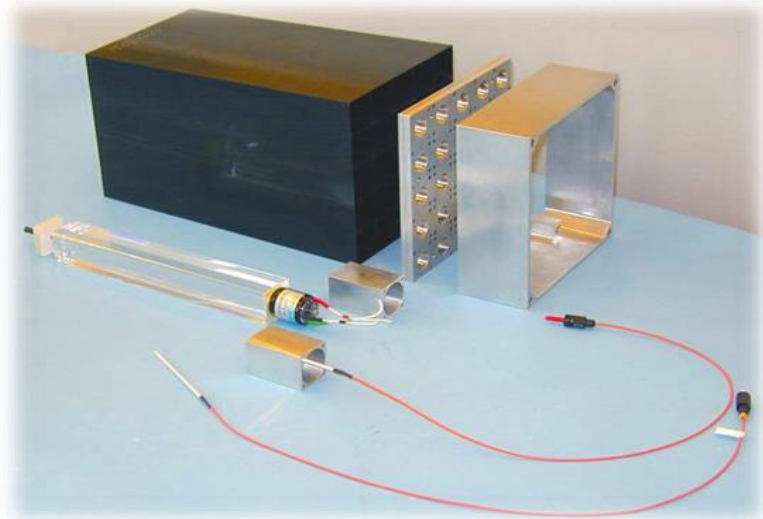
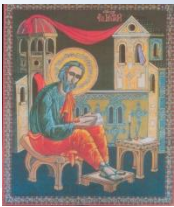
- **Fast scintillation:**
- **80% of the light collected in 25 ns**
- **Radiation length: 0.89 cm**
- **Moliere radius : 2.19 cm**





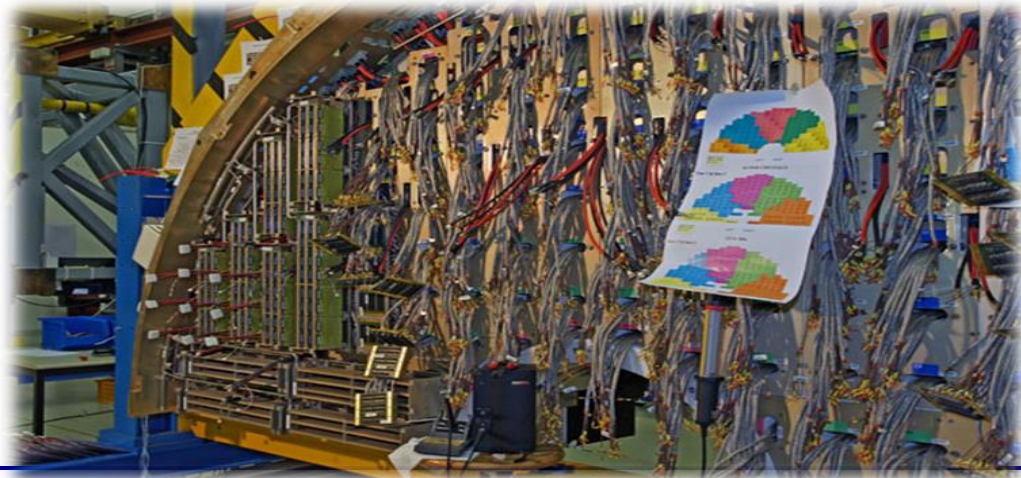
ECAL modules





4 "Dees" of 156 SCs each

- Installation and all tests of all 4 Dees completed just before closing LHC tunnel for the first beam test on 12 September 2008



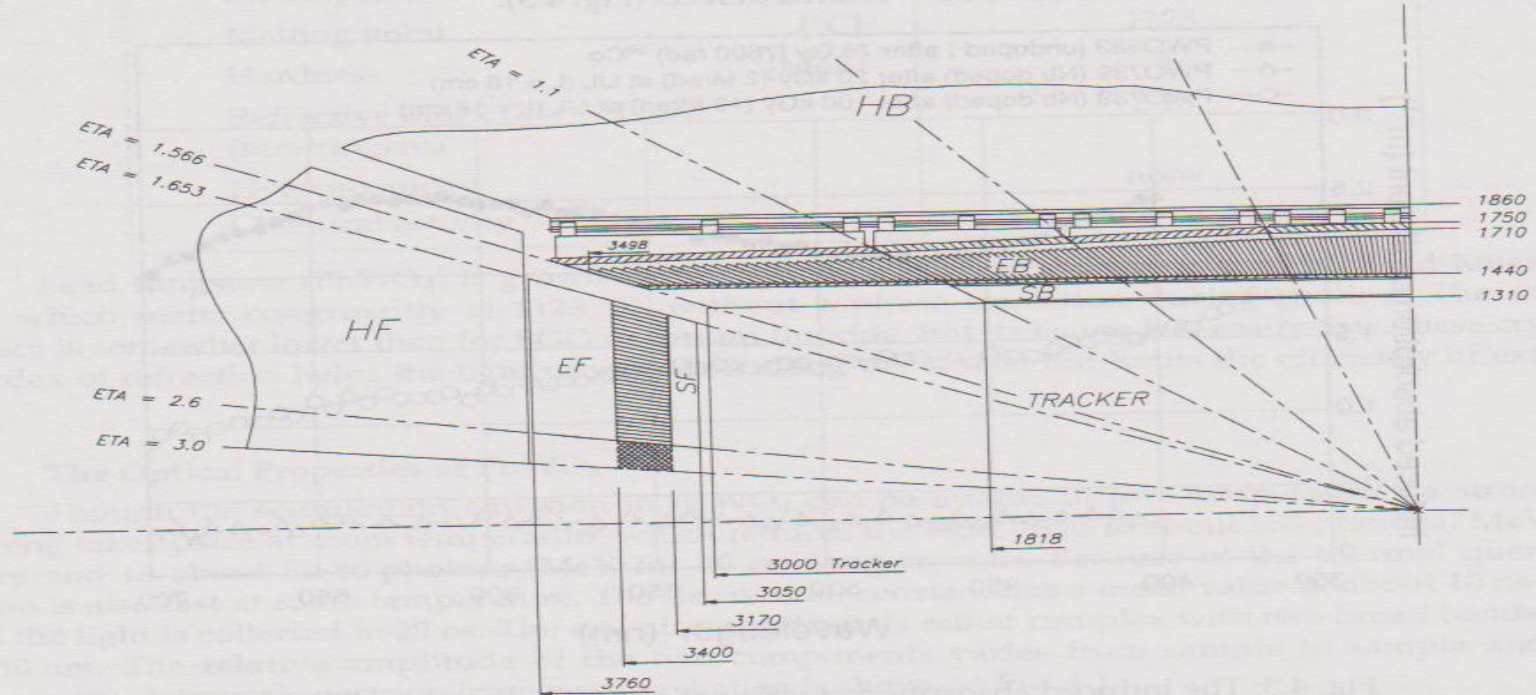
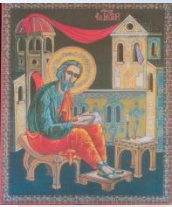
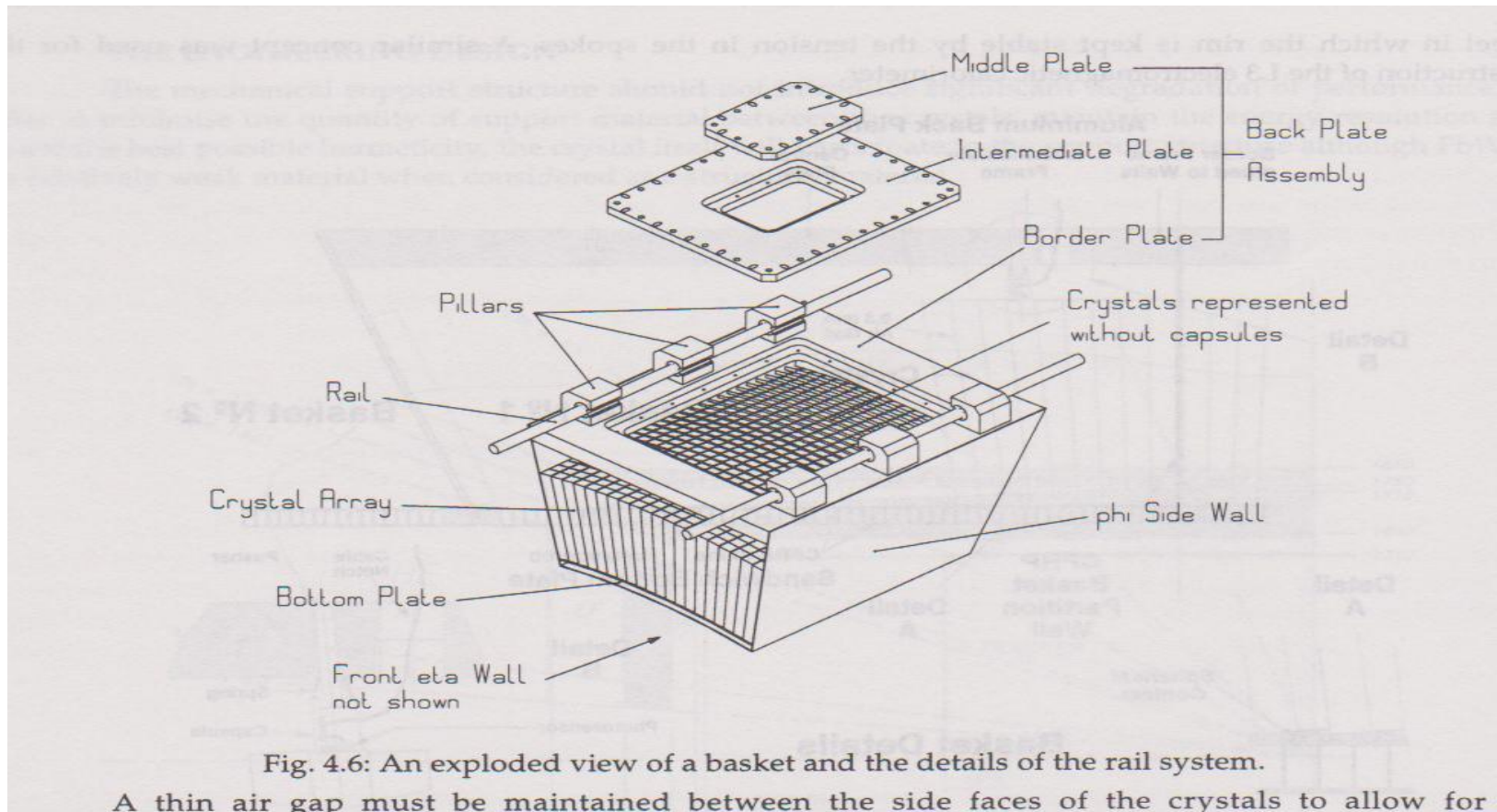
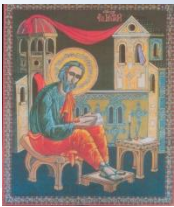


Fig. 4.4: The layout of the barrel and endcap PbWO_4 electromagnetic calorimeter.

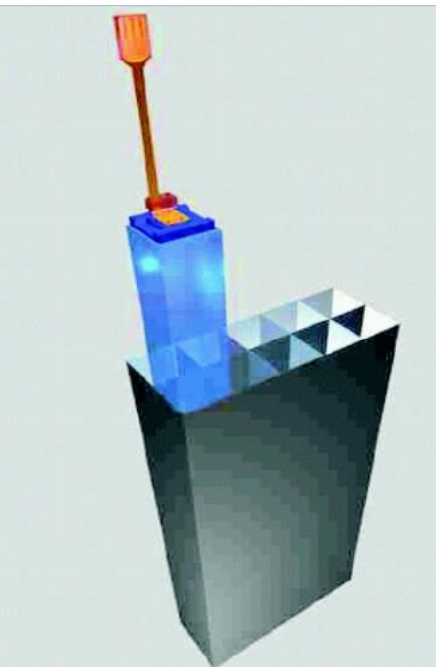
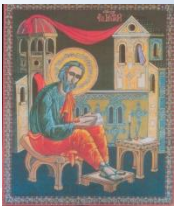
Проект на направленията на кристалите в BARREL и END CAPS в ECAL

Национална учителска програма за квалификация на инженери - педагози

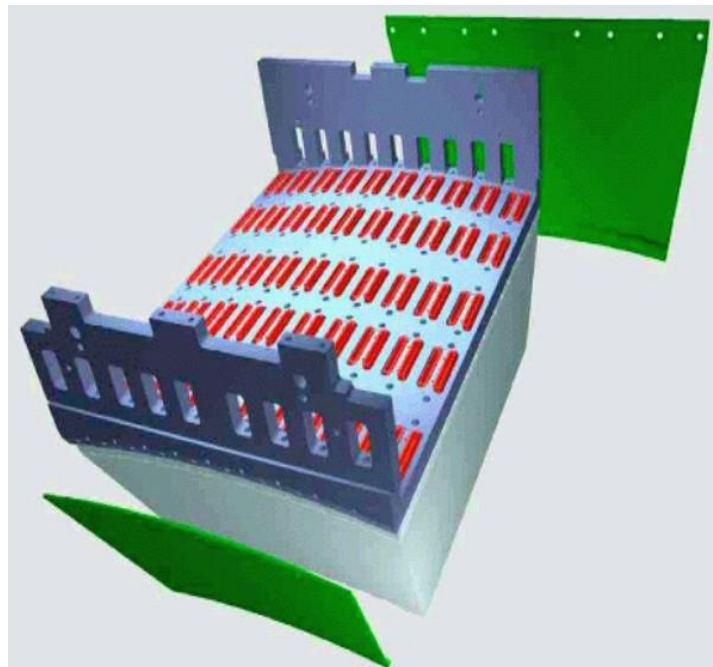
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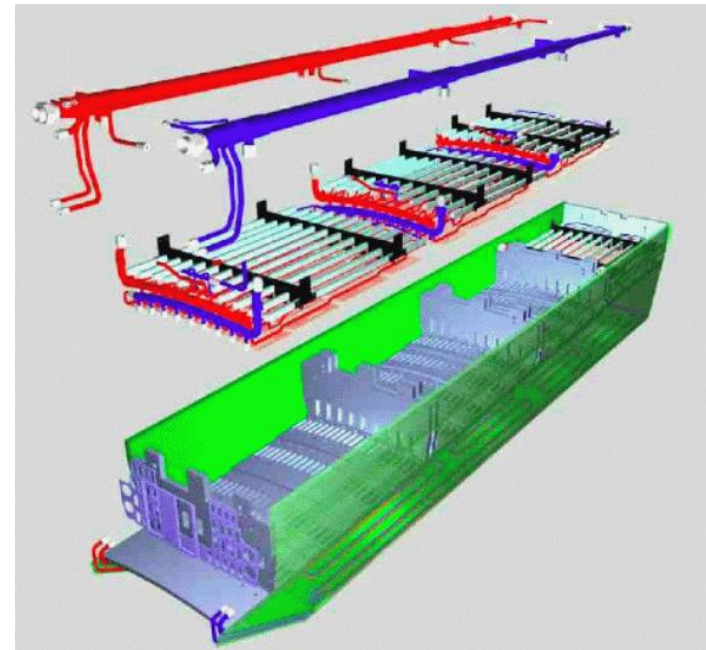
Проект на конструкцията на “кошница” за разполагането на кристалите в ЕСАЛ



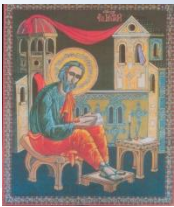
Алвеолен модул



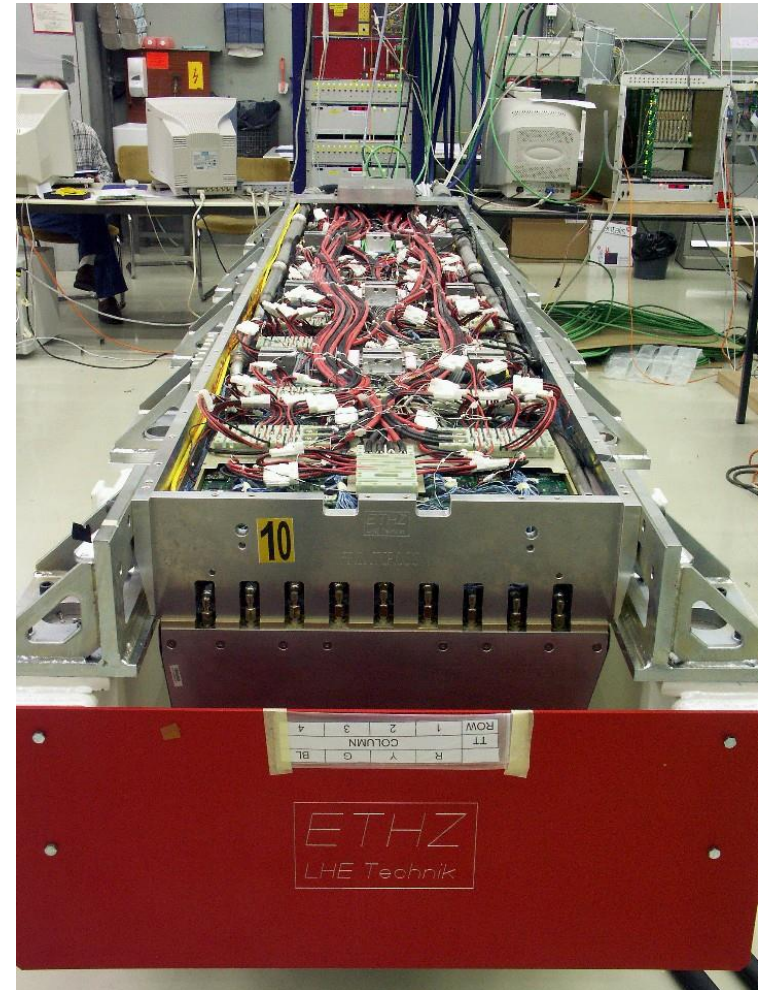
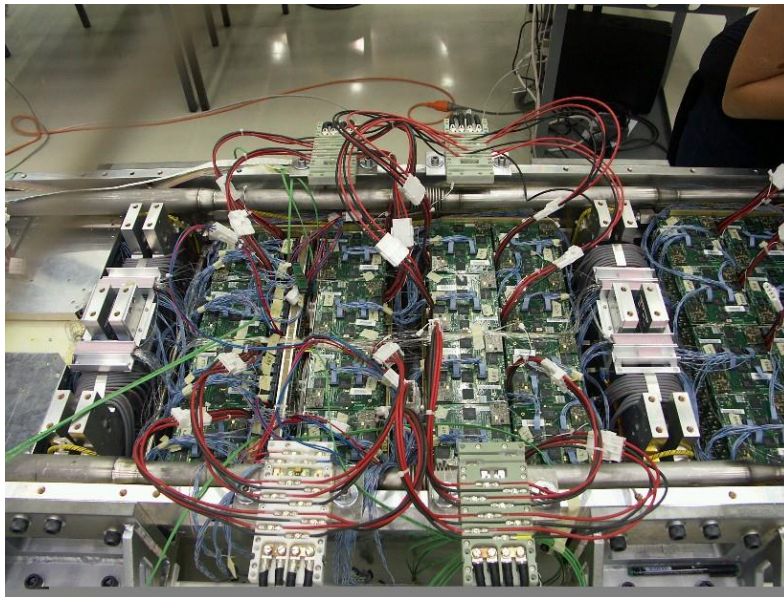
Модул тип “Кошница”

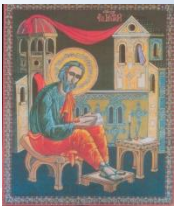


Супер модул



Монтаж, настройка и тестване на супермодул в лабораторни условия

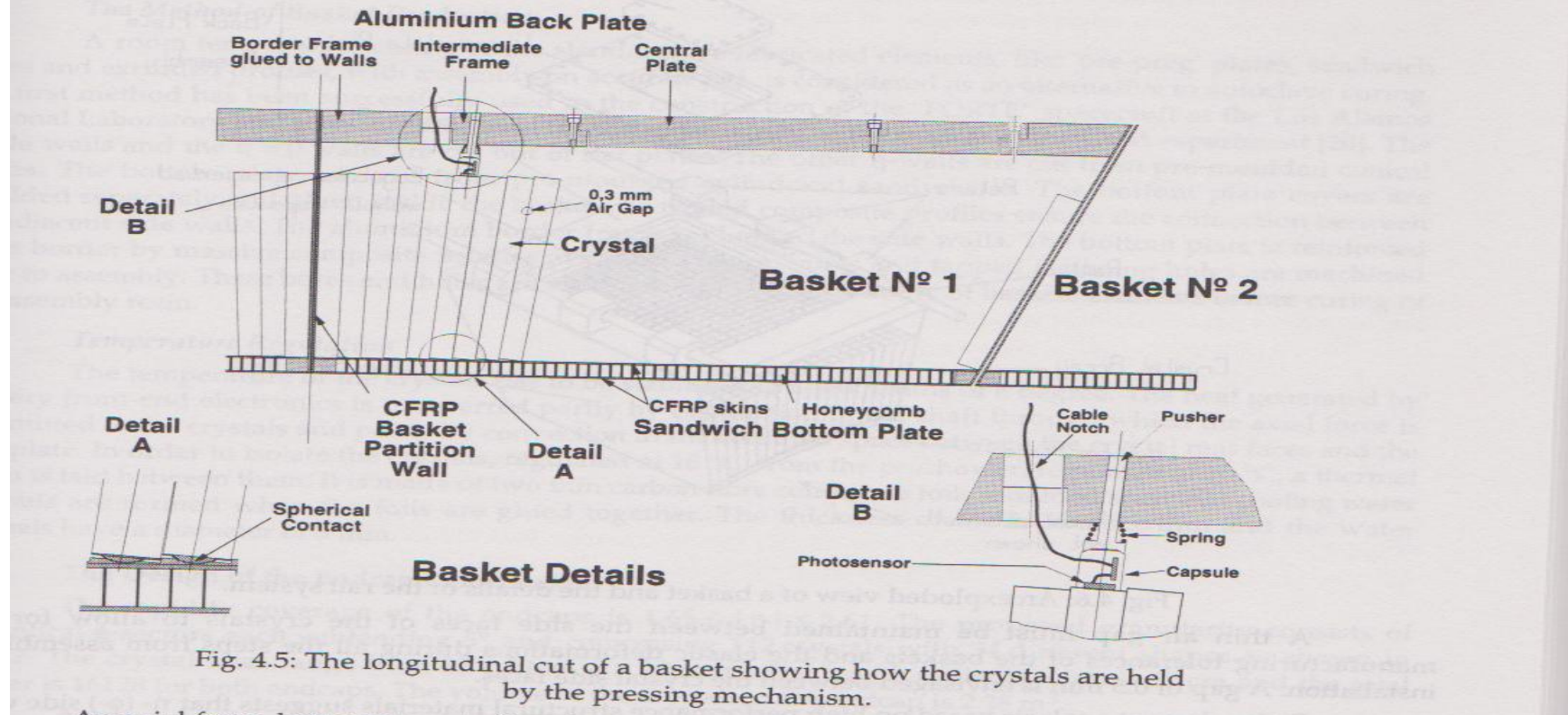




ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА - БАН



steel in which the rim is kept stable by the tension in the spokes. A similar concept was used for the construction of the L3 electromagnetic calorimeter.



Проект на разположение на кристалите и начин на закрепването им в ECAL

Национална учителска програма за квалификация на инженери - педагози

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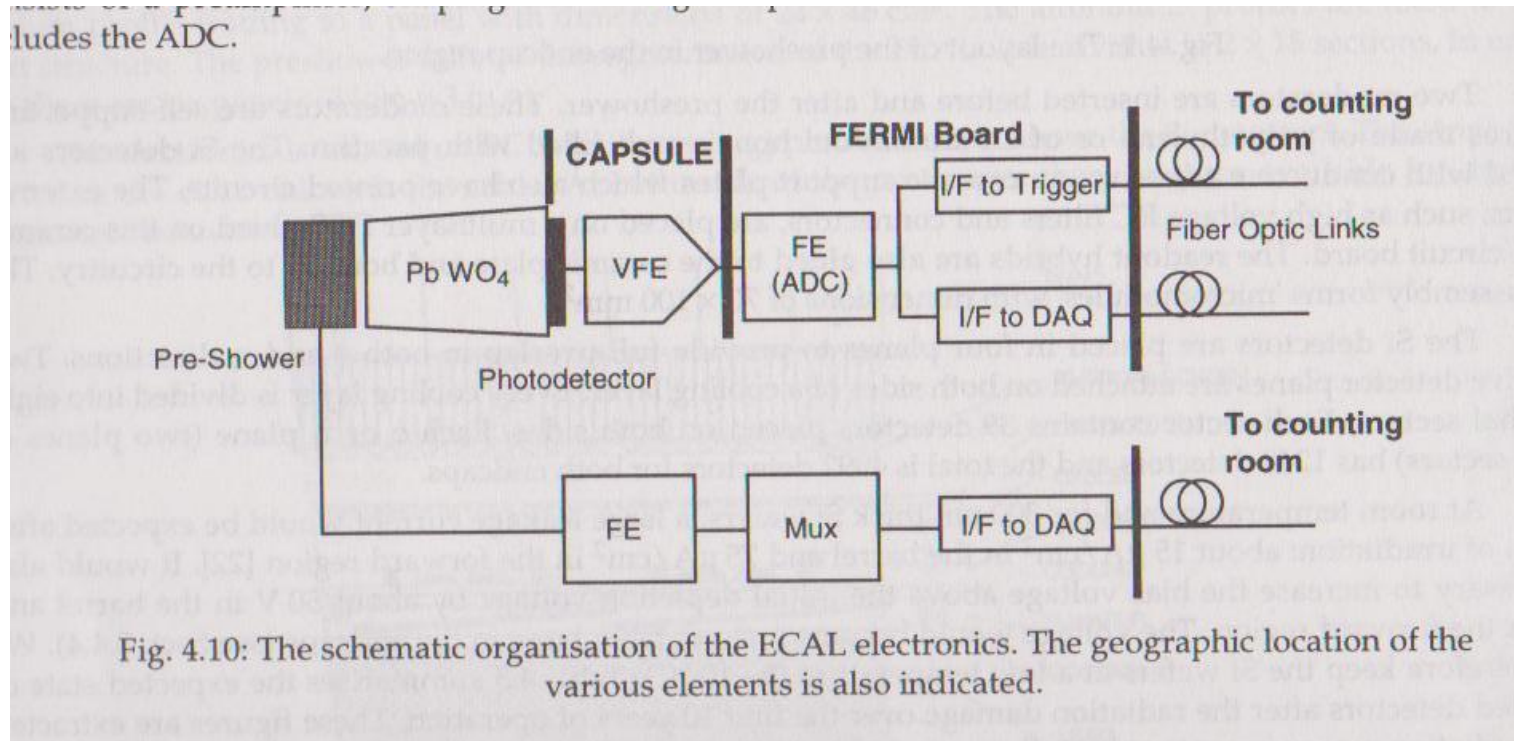
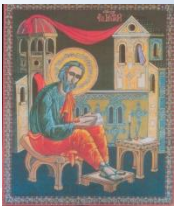
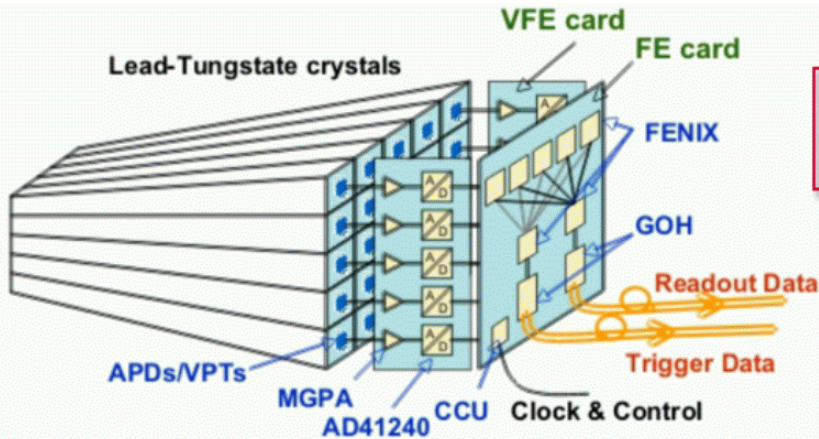
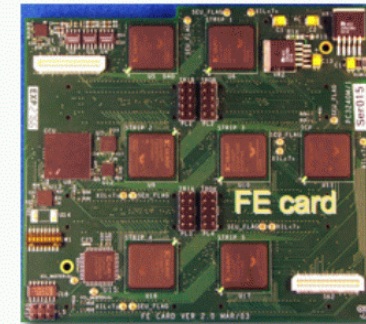
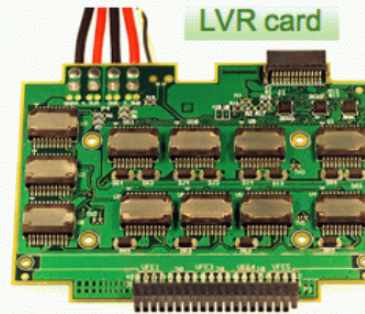
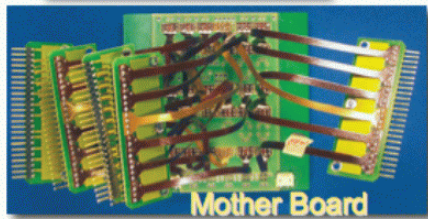
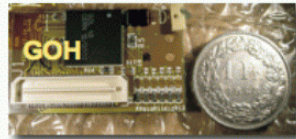
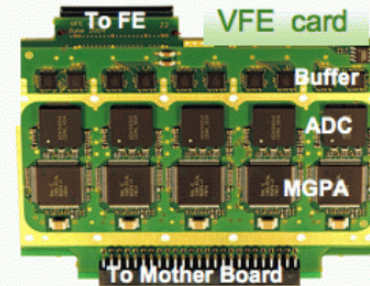


Схема на електрониката на предния край на ECAL,CMS



The ECAL readout electronics



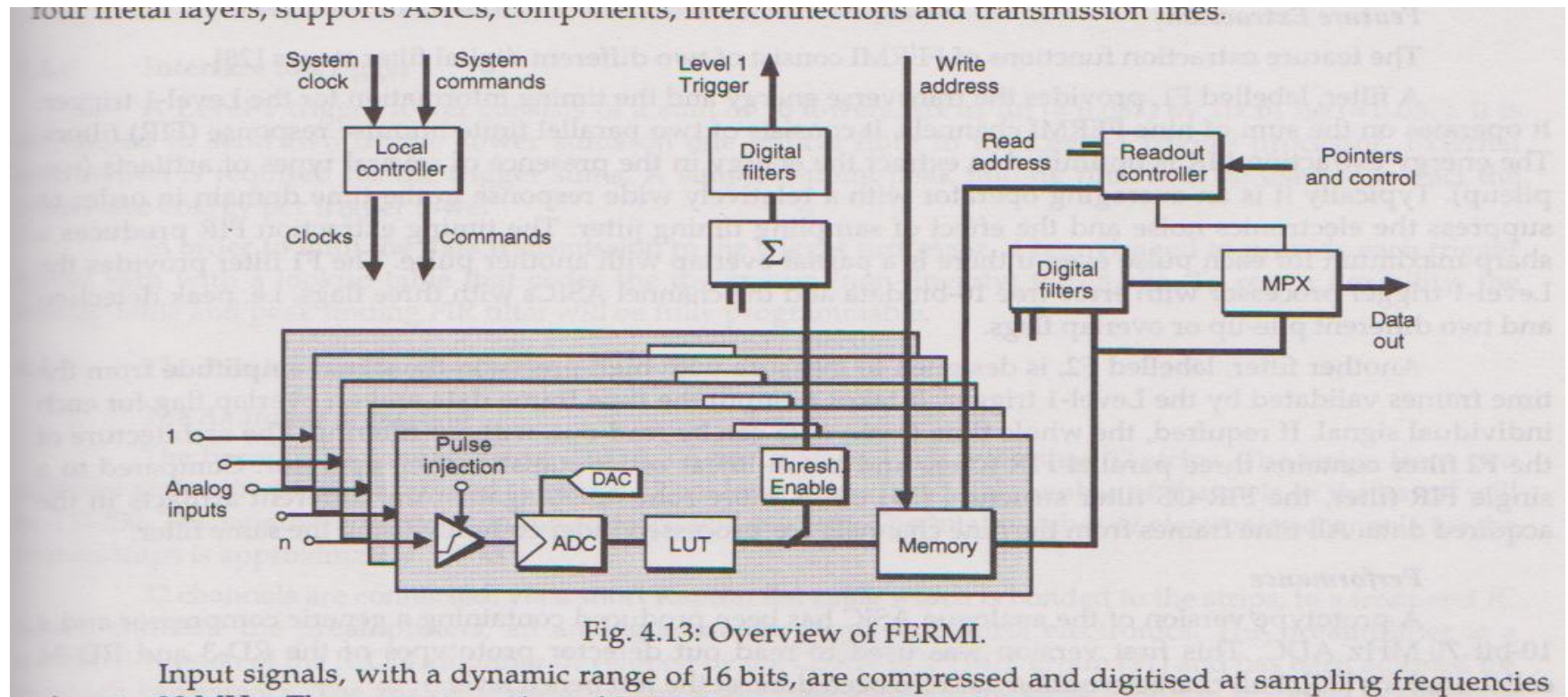
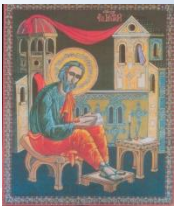
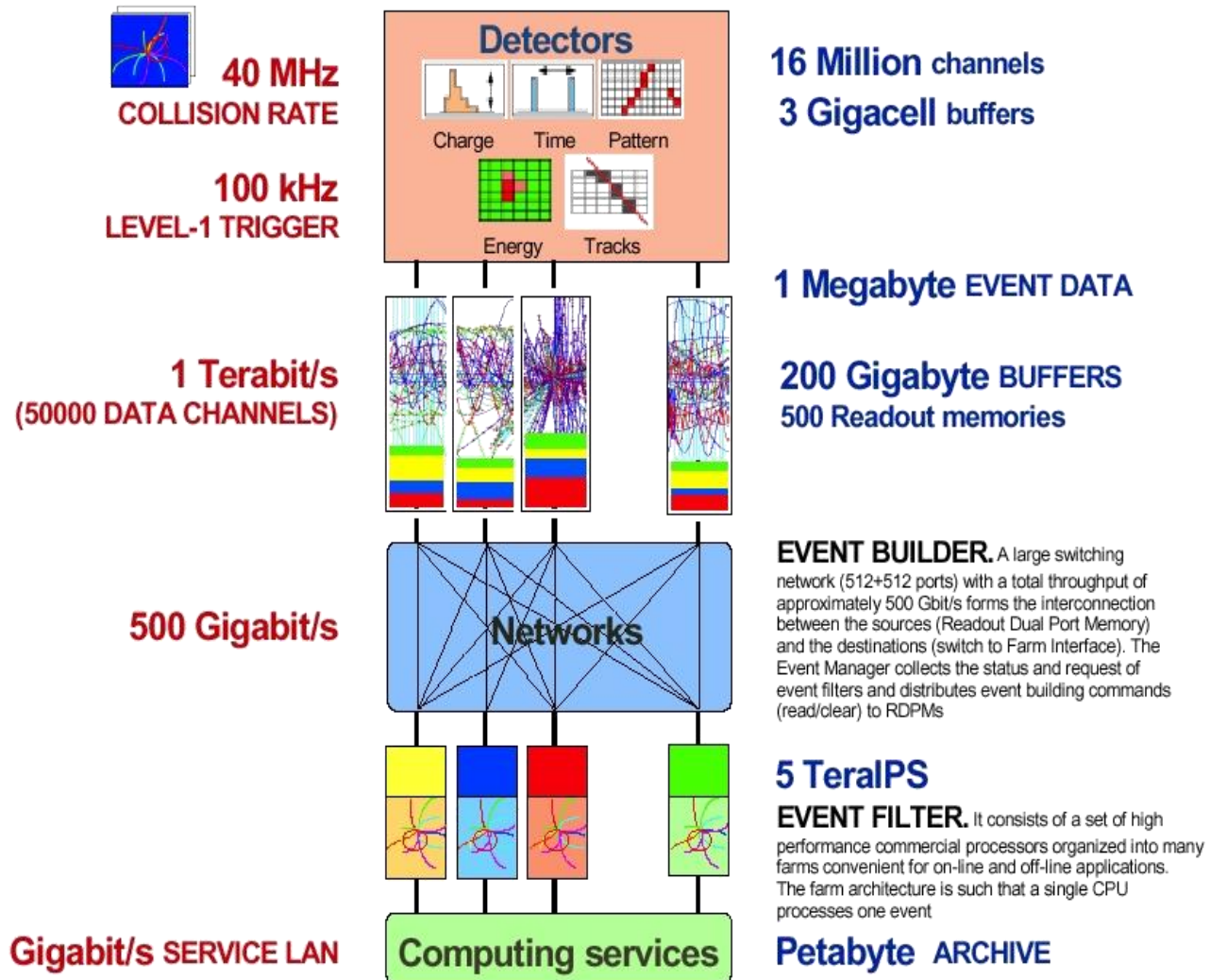
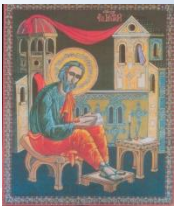
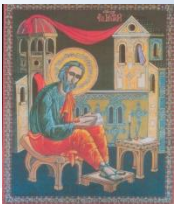


Схема на електрониката за формиране на данните на ECAL,CMS





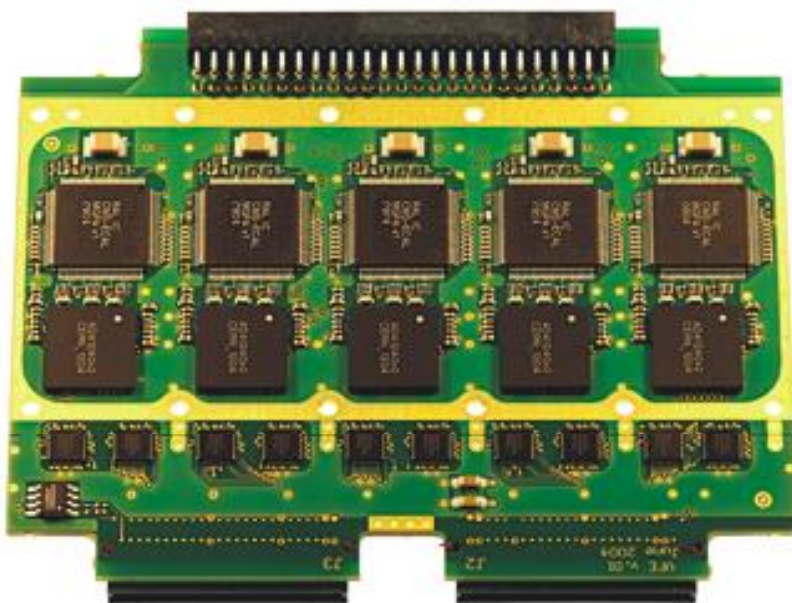
Very Front End Electronics

digitize once every 25 ns the energy in all crystals

MGPA

ADC

LVDS_Rx

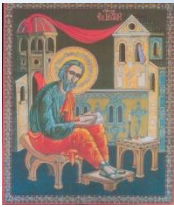


ENC: 8000e- gain 6, 12

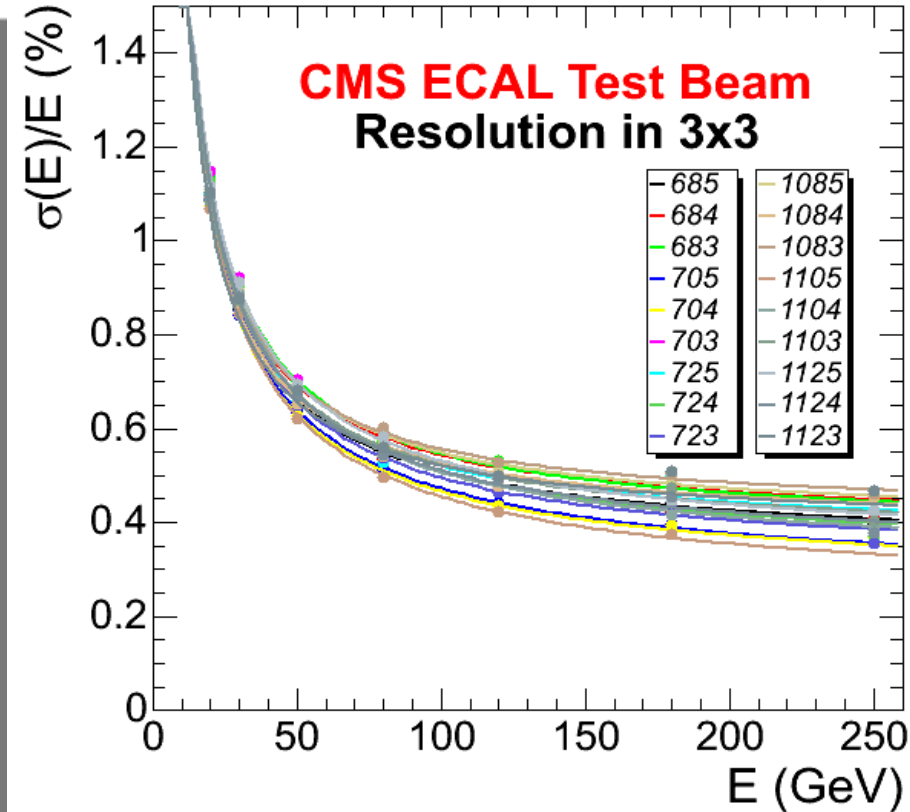
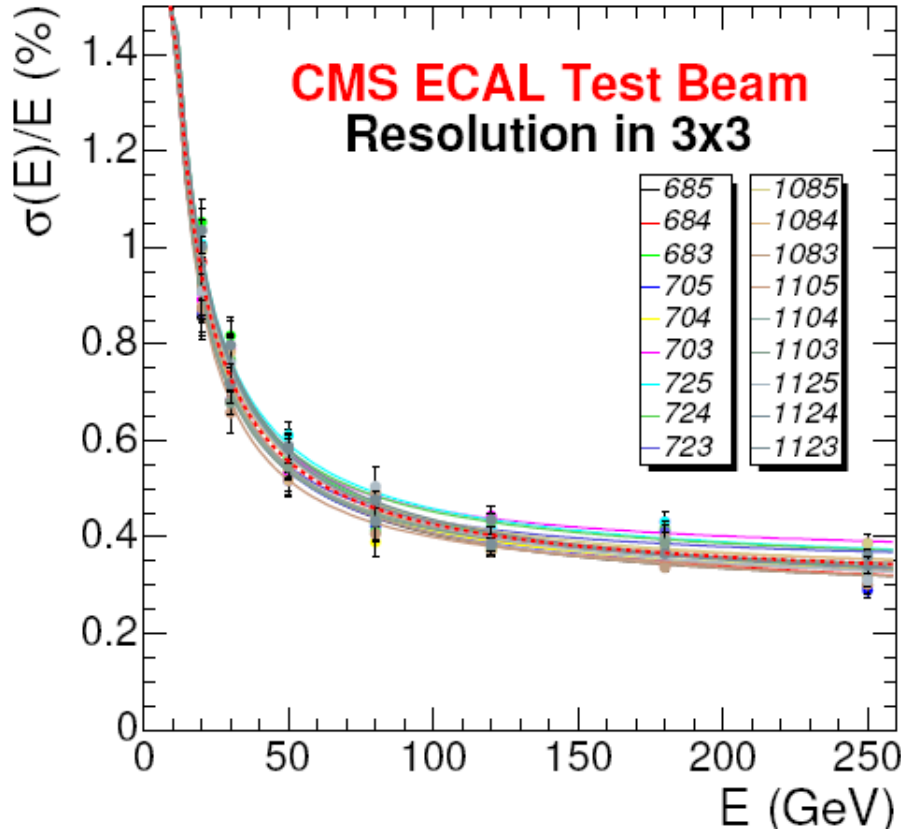
ENC: 28000e- gain 1

Noise: ~40 MeV (g12)

ADC: 12 bit (ENOB 10.9), 40 MHz

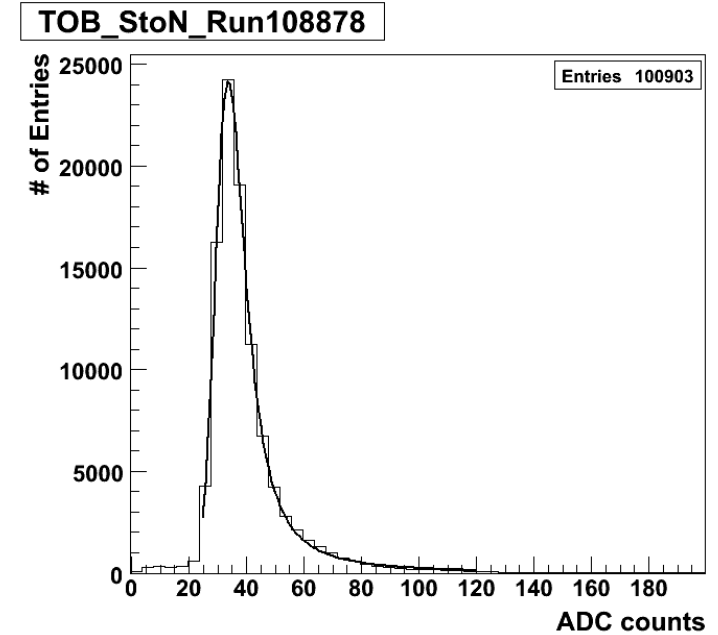
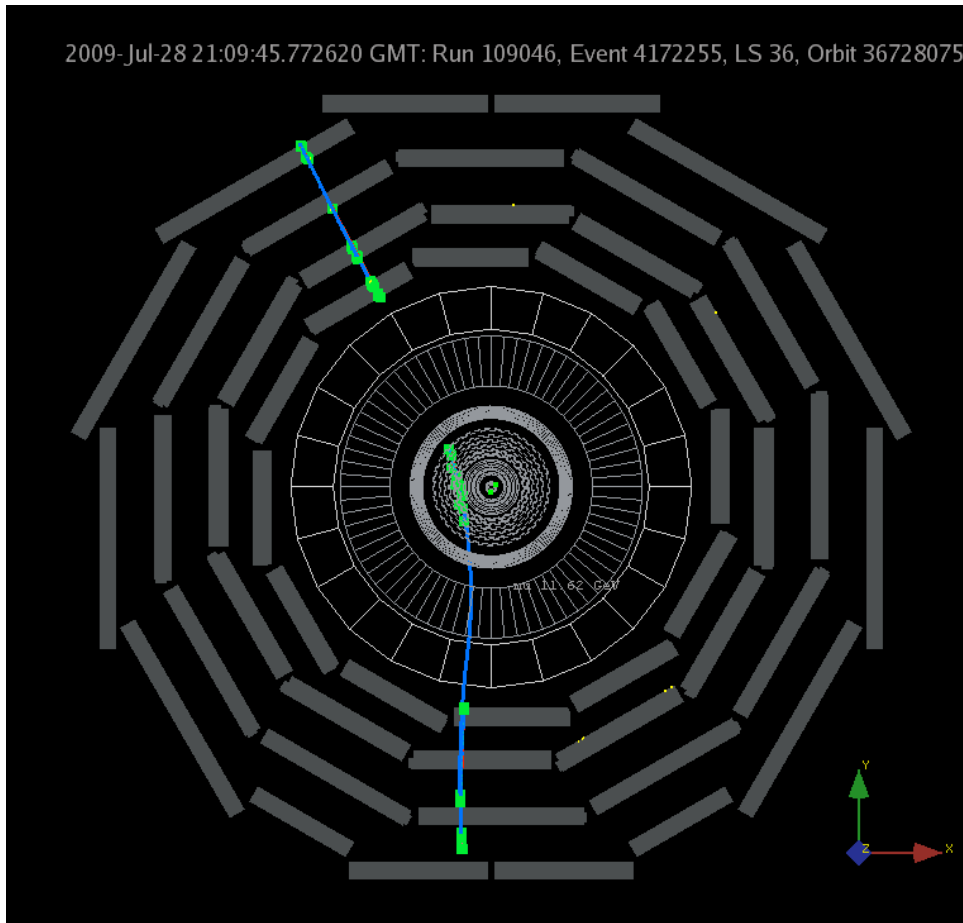


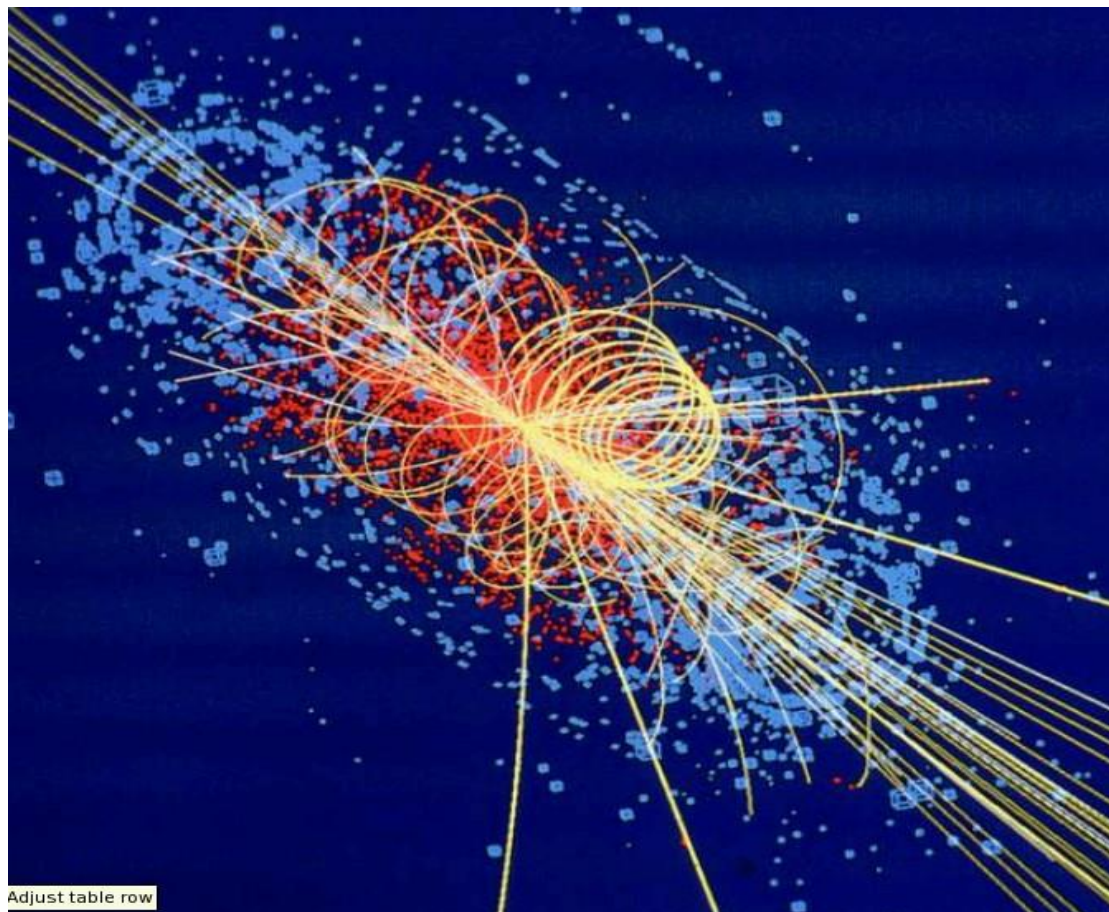
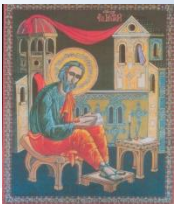
Energy Resolution





3.8TeV Събитие

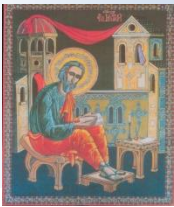




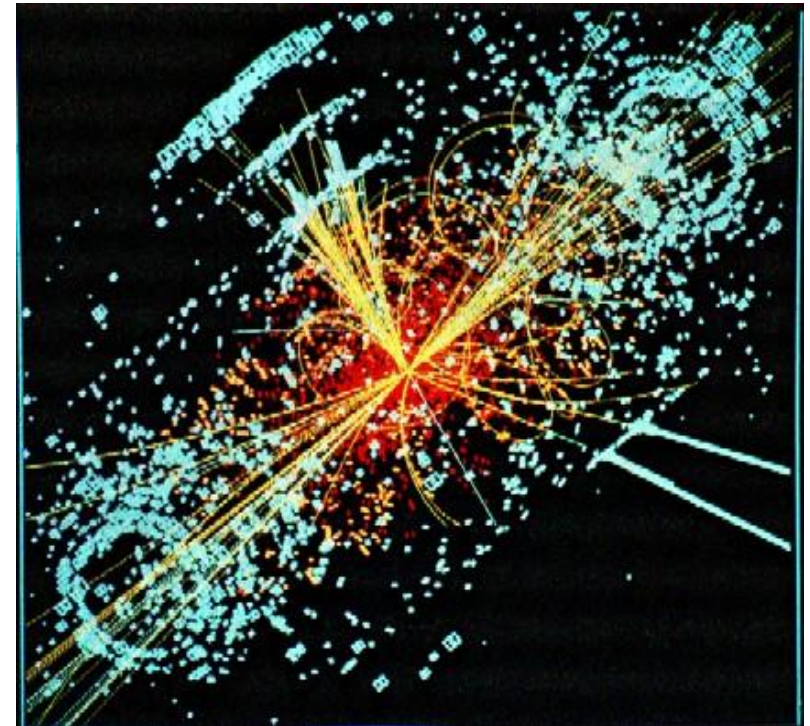
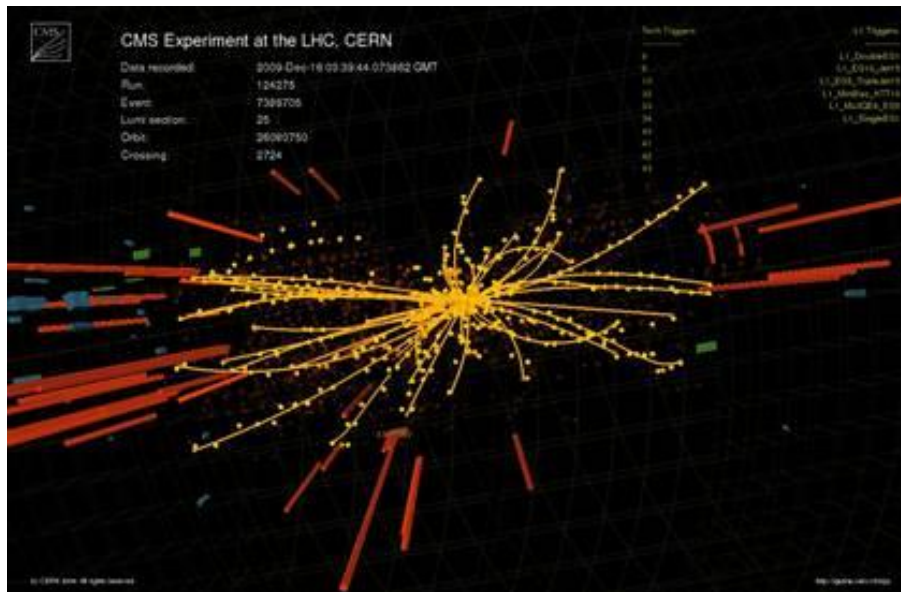
Протон – протон взаимодействие в CMS

Национална учителска програма за квалификация на инженери - педагози

Женева, 04-10.10.2015 г.

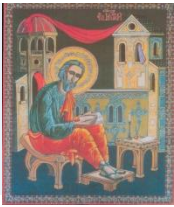


Събитие



CMS ~ 100 милиона канала

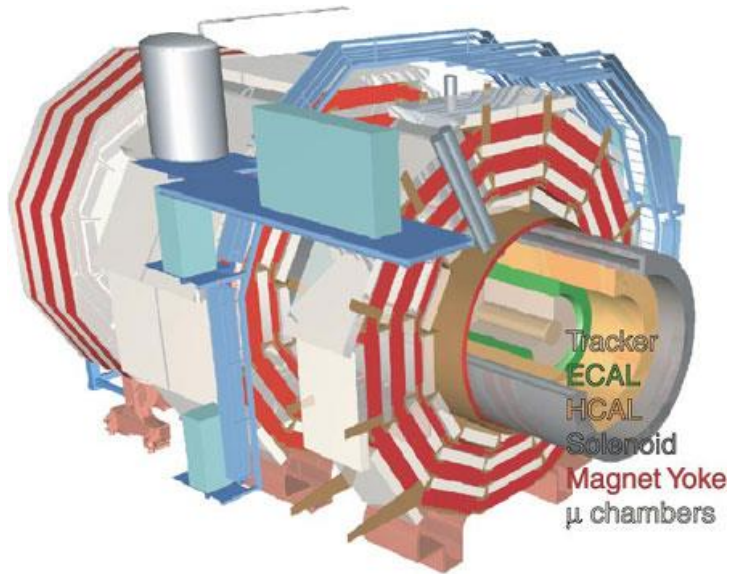
цифрова камера ~ 6 милиона пиксела, но CMS прави “цифрова снимка” 40 милиона пъти в секунда !!



Приноси на ИСИР-БАН при конструирането на CMS Detector at LHC



От 1998 участие в конструирането на CMS detector



Electronics Integration of the CMS Electromagnetic Calorimeter

(W. Lustermann)

Bonding of TEC modules for the Silicon Strip Detector

(W. Lustermann, K. Freudenreich)

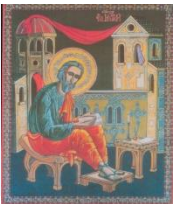
Participation with CAD experts in the Engineering and Integration Center of CMS

(G. Faber, A. Ball)

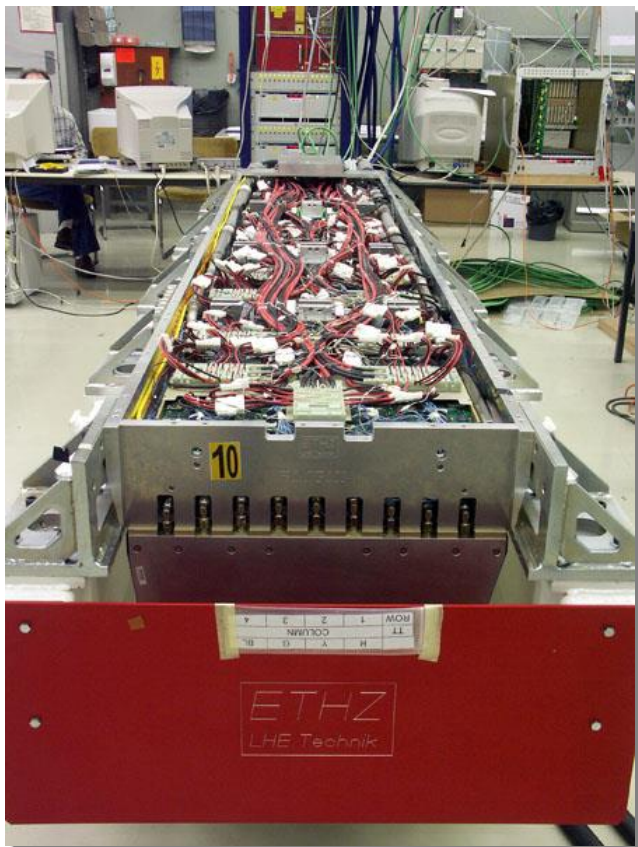
Work on the CMS Equipment Management Database

(G. Faber, A. Ball)

Like for L3, all activities in CMS are carried out in the framework of a collaboration agreement with the Institute for High Energy Physics of ETH Zurich.



Участие в интегрирането на електрониката в CMS Electromagnetic Calorimeter



Preparation of the infrastructure and of the integration stands in the ECAL integration center.

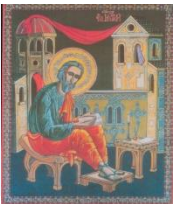
Construction of an ECAL Single Trigger Tower test stand.

During 2006 and 2007 participation in the ECAL barrel electronics integration and commissioning effort.

ECAL Cable production.

Coordination: W. Lustermann (ETH Zurich)

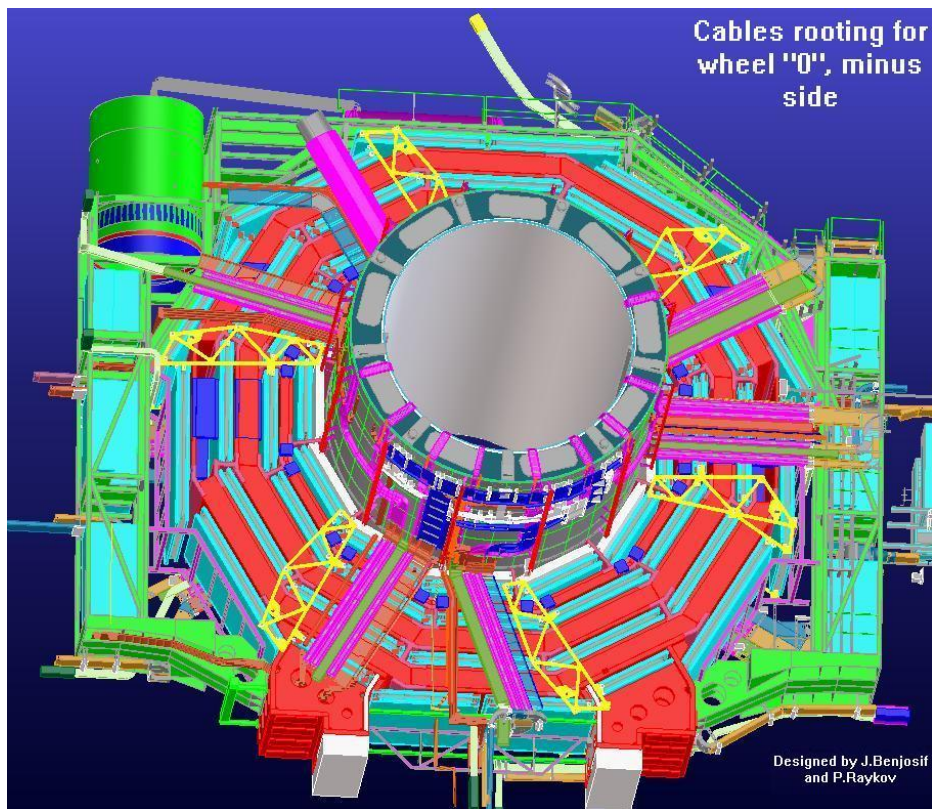
ISER-BAS participants: R.Zahariev, S. Stoenchev, E. Petrov, K. Stanishev, K. Zagurski, A. Hristov, M. Peynekov, G. Georgiev, D.Lichkov



Дейност в CMS Engineering and Integration Center



Example of cable routing design for the CMS Tracker



Cable routing design

Design of the cable tray cooling

Measurement device design

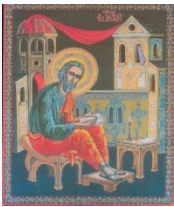
Tower for observation and service

Coordination:

G. Faber (ETH Zurich)

A. Ball (CERN)

ISER–BAS participants: J. Beniozev,
P. Atanasov, K. Mihovski



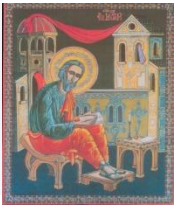
Създаване на база данни за мениджмънт на CMS Екипировката



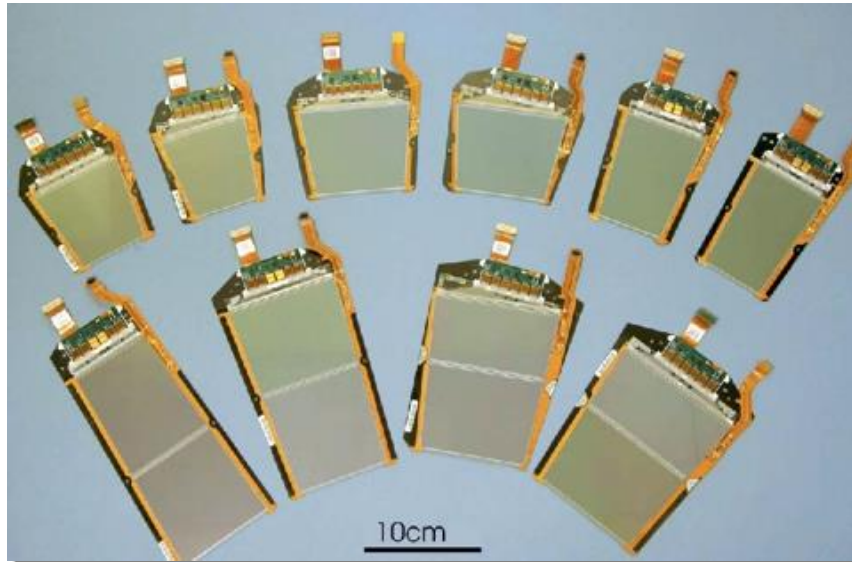
ISER-BAS participates in development of the new CMS Equipment Management Database including an easy to use WEB interface. This Database will collect all information about the equipment, installed in the CMS detector.

Coordination:
G. Faber (ETH Zurich)
A. Ball (CERN)

ISER-BAS participant:
D. Uzunova,
F.Georgieva -TU Sofia



Технология по залепване на TEC Modules at ETH Bonding Lab at CERN

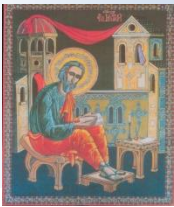


**Bonded and tested 1091 TEC modules
(4 different geometries)**



G. Petrov, V. Alexandrov
(2 FTEs for 3 years)

Coordination: W. Lustermann and
K. Freudenreich
(ETH Zurich)



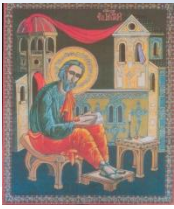
ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА - БАН



Група участници от ИСИР-БАН, с колеги от Института за ядрени изследвания – БАН, и ETH-Zurich, заедно с доайена на българската група проф. Ботьо Бетев

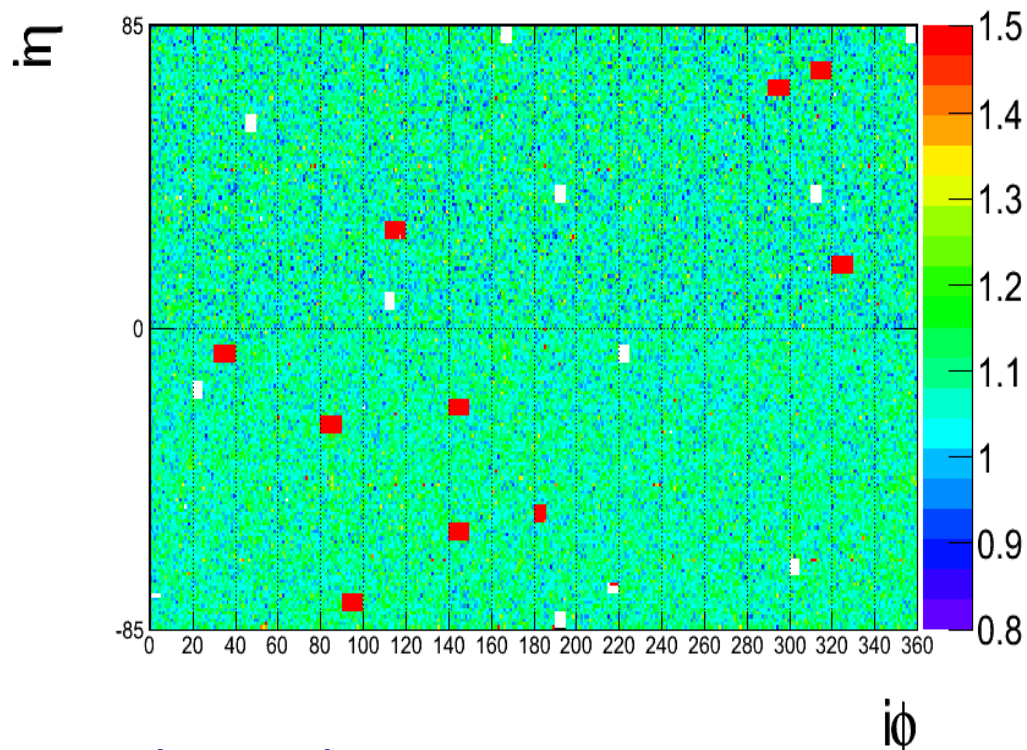
Национална учителска програма за квалификация на инженери - педагози

Женева, 04-10.10.2015 г.

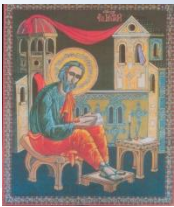


Състояние на Barrel след поправка на LV кабели

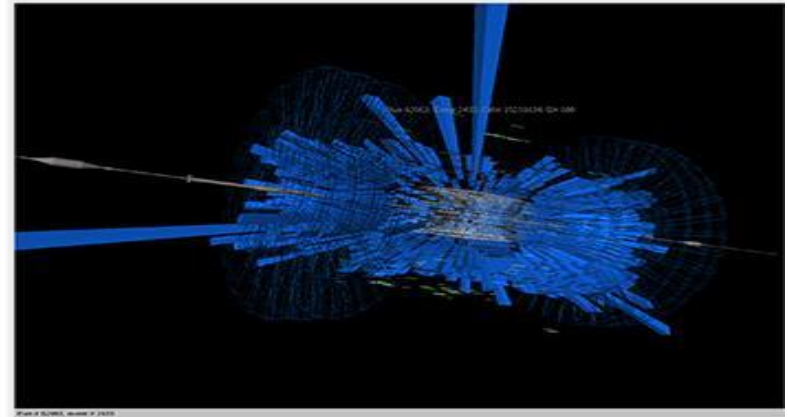
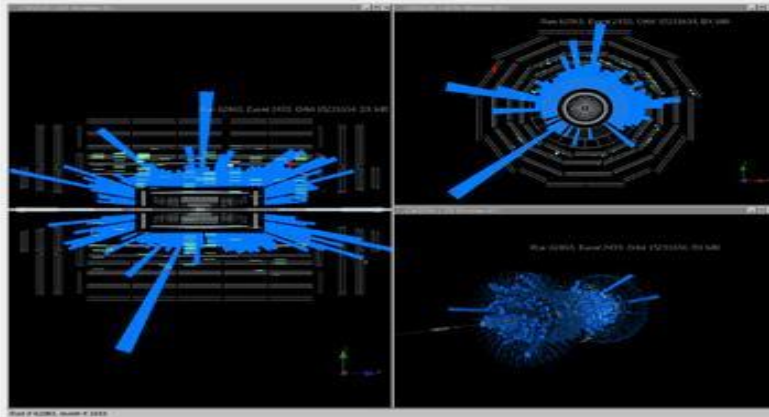
Start runs in 2009: Pedestal RMS, Gain 12 (ADC Counts)



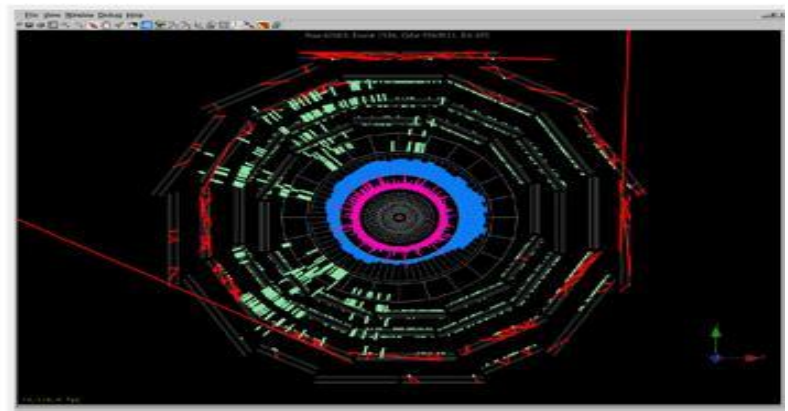
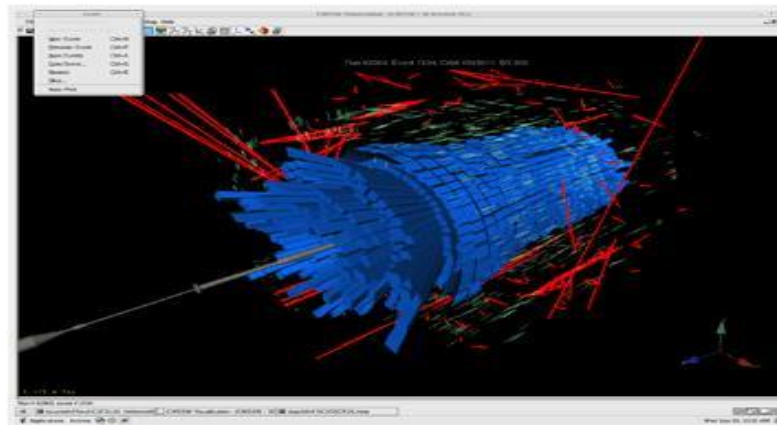
60934 от 61200 (99.57 %) Very Front End channels SA АКТИВНИ!



ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА - БАН



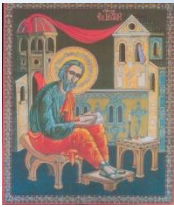
Debris from particles hitting the collimator blocks were detected in the calorimeters and muon chambers.



The first beams were circulated successfully on 10 September 2008

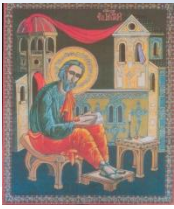
Национална учителска програма за квалификация на инженери - педагози

Женева, 04-10.10.2015 г.



Изводи и заключения:

- Монтажа, настройката и тестването на електрониката на всички 36 супер модула (61200 канала) на ЕСАЛ е завършена в блок 867 през юли 2007 г. успешно.
- Инсталирането на Барела на ЕСАЛ и тестването му в “Точка 5” на ускорителя е завършено декември 2007 г. успешно.
- Инсталирането и тестването на крайните шапки на ЕСАЛ, 4 части (14568 канала) в блок 867 завършва през юли 2008 г. успешно.

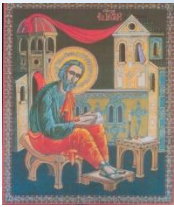


Изводи за състоянието на ECAL

Инсталирането и тестването на крайните шапки 4 части (14568 канала) в точка 5 на ускорителя окончателно завършва през септември 2008 г. успешно.

В първоначалните тестове на CMS, ECAL се включва успешно от септември до ноември 2008 г.

От началото на 2009 г. до сега ECAL работи безотказно, като неговата роля се оказва определяща при следващите експерименти, завършили с голям успех.



ИНСТИТУТ ПО СИСТЕМНО ИНЖЕНЕРСТВО И РОБОТИКА - БАН



БЛАГОДАРНОСТИ:

- На Министерството на образованието и науката на България и на Дирекция “Квалификация и кариерно развитие” за организацията на Националната учителска програма за квалификация на инженери – педагози.
- На Образователната група към CERN за поддръжката, която оказва на организирането на Националната учителска програма.

БЛАГОДАРЯ ЗА ВНИМАНИЕТО!